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DEPARTMENT OF AGRICULTURE.
DIVISION OF CHEMISTRY.
BULLETIN No. 8.

METHODS AND MACHINERY

FOR THE

APPLICATION OF DIFFUSION

TO THE

EXTRACTION OF SUGAR FROM SUGAR CANE AND SORGHUM,

AND FOR THE USE OF

LIME, AND CARBONIC AND SULPHUROUS ACIDS

IN

PURIFYING THE DIFFUSION JUICES.

HARVEY W. WILEY,
CHEMIST.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1886.

12977—No. 8

LETTER OF TRANSMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
DIVISION OF CHEMISTRY,
Washington, D. C., March 10, 1886.

SIR: I have the honor to submit for your approval a report of recent investigations on methods and machinery for the extraction of sugar from cane and the processes for the purification of the extracted juices.

Respectfully,

H. W. WILEY,
Chemist.

Hon. NORMAN J. COLMAN,
Commissioner.

METHODS AND MACHINERY FOR EXTRACTION OF SUGAR FROM CANE, AND PROCESSES FOR PURIFICATION OF EXTRACTED JUICES.

1. THE APPLICATION OF DIFFUSION TO THE EXTRACTION OF SUGAR FROM CANE.

In 1883 the Department of Agriculture undertook a series of experiments to test the possibility of applying the process of diffusion to the extraction of sugar from cane. The great waste of saccharine matter by the method of pressure was the chief incentive to the experiments. But further than this, it was believed that the process of diffusion was more rational, less expensive, and less subject to accident than the use of rolls. The results of these experiments were published in Bulletin No. 2, of the Division of Chemistry of the Department of Agriculture. In this bulletin was given a brief history of the use of the process of diffusion in Europe with the sugar beet, a statement of the theory of diffusion with mathematical formulæ showing the progress of saturation of the juices, and also a history of an attempt to introduce the process into Louisiana ten years previously, with a discussion of the causes of failure of the undertaking. This was followed by a concise report of the experiments made by the Department.

Since this bulletin is out of print I will give here a brief summary of the results of the work:*

Careful analyses were made during the process of the experiments to determine the completeness of the extraction and the character and quality of the diffusion juices, and to compare them with the juices of the same canes obtained from the mill.

The diffusion cells held 18.2 kilograms (40 pounds) of chips. This quantity was weighed and put in each cell. The cell, after being filled with chips, would still hold nearly 22 kilograms of water (48 pounds). The exhausted chips were found to have increased in weight, so that each cellfull weighed nearly 22 kilograms. The charge and discharge of the cell, therefore, are represented by the following table:

	Kilograms.
Weight of fresh chips taken	18
Weight of exhausted chips	22
Weight of diffusion juice drawn off	22
Weight of waste water	22
Per cent. diffusion juice to weight of chips	122

Each 100 parts chips gave of juice 122 parts.

* Bulletin No. 2, pp. 27 *et seq.*

On November 14 I obtained the following data: *

Analyses.

Diffusion juice, November 14:	
Specific gravity	1.0406
Sucrose	6.04
Other sugars	2.16
Purity	67.5
Total solids	9.05
Mill juice, same cane and date:	
Specific gravity	1.065
Sucrose	9.95
Other sugars	3.29
Purity	64.4
Total solids	15.13
Melada obtained, 196.4 kilograms (by diffusion):	
Per cent. sucrose	52.50
Per cent. other sugars	20.85
Weight of chips diffused, kilograms	1,596
Weight of juice obtained, do	1,929
Weight of sucrose in *masse cuite*, do	103
Percentage of *masse cuite* to cane	12.28

LOSS OF SUGAR.

The pulp from the 1,596 kilograms of cane weighed 1,929 kilograms. It contained .12 per cent. sucrose and .06 per cent. other sugars.

Then 1,929 × .0018 = 3.47 kilograms of sugar lost in pulp.

The waste water from the above weighed 1,929 kilograms. It contained .01 per cent. of sucrose and .07 per cent. other sugars.

Then 1,929 × .0008 = 1.54 kilograms of sugar lost in waste water.

Total loss in both, 5.01 kilograms.

Another † trial was made on Tuesday, November 20, of the same kind of cane as above (Link's Hybrid) which had been frozen on the preceding Thursday, and left since that time lying in the yard.

Run of November 20, 1883.

	Kilograms.
Weight of chips diffused	1,447.8
Weight of juice obtained	1,738.0
Weight of pulp obtained	1,738.0
Weight of waste water obtained	1,738.0
Weight of semi-sirup	276.3
Weight of *masse cuite*	157.8

Analyses November 20, 1883.

Samples analyzed.	Sucrose.	Other sugars.
Chips	7.68	3.38
Mill juice	9.58	3.70
Diffusion juice	5.63	2.50
Pulp (exhausted chips)	0.10	0.06
Waste water	0.026	0.027
Semi-sirup	28.94	12.58
Masse cuite	48.83	22.15

* Bulletin No. 2, p. 29. † Bulletin No. 2, pp. 30 *et seq.*

RESULTS.

Percentage of *masse cuite* to cane diffused = 10.9.
Total weight of sugar in diffusion juice was 1,738 × .0813 = 141.30 kilograms.
Total weight of sugar in pulp was 1,738 × .0016 = 2.77 kilograms.
Total weight of sugar in waste water was 1,738 × .00053 = 0.92 kilogram.
Total weight of sugar in cane = 141.30 + 2.76 + .92 = 144.98 kilograms.
Total loss in diffusion, 3.69 kilograms.
Per cent. of loss in diffusion, 3.04.
Total weight of sugar in semi-sirup was 276.3 × .4152 = 114.72 kilograms.
Loss during evaporation to semi-sirup was 141.30 − 114.72 = 26.58 kilograms.
This loss was due to wastage, scum, and especially to the sediment and gum separated during defecation and which could not be filtered.

MASSE CUITE.

Total weight of *masse cuite*, 157.8 kilograms.
Total weight of sugar in *masse cuite* = 157.8 × .7079 = 112.00 kilograms.
Loss in reduction from semi-sirup to *masse cuite* = 114.72 − 112.01 = 2.71.

*Mean of thirty-seven analyses of diffusion juices.**

Specific gravity		1.0340
Total solids	per cent.	8.021
Total sugars	do	7.36
Sucrose by direct polarization	do	4.80
Sucrose by double polarization	do	4.95
Coefficient of purity		61.80
Other sugars	per cent.	2.42
Of ash	do	.3571
Of nitrogen	do	.0316
Of albumen	do	.1976
Of nitrogen as amides	do	73.30

Mean of twenty-four analyses of mill juices. †

Specific gravity		1.0639
Total solids	per cent.	14.810
Total sugars	do	13.12
Sucrose by direct polarization	do	8.58
Sucrose by double polarization	do	9.04
Coefficient of purity		60.40
Other sugars	per cent.	4.08
Ash	do	.5606
Nitrogen	do	.0467
Albumen	do	.2921
Nitrogen as amides	do	76.70

Mean of thirty-four analyses of waste waters.

Total sugars	per cent.	.191
Sucrose by direct polarization	do	.094
Other sugars	do	.102

Mean of thirty-five analyses of pulps. ‡

Total sugars	per cent.	.534
Sucrose by direct polarization	do	.468
Other sugars	do	.159
Ash	do	.2736

* Bulletin No. 2, p. 31. † Bulletin No. 2, p. 32. ‡ *Op. cit.*, p. 33.

The * experiments in diffusion I freely admit are far from being satisfactory. I think, however, that a great deal can be learned from acquiring a practical idea of the nature of the defects in any new process. I consider the following to be the chief faults in the experiments made:

I aimed to secure a diffusion juice of about the same density as the diffusion juice from the beet as obtained in the European factories. I am convinced now that this was a mistake. If a mill juice shows a density of 1.062, I think a diffusion juice should have one of not less than 1.050. In fact I think the volume of the diffusion juice should represent a weight not much greater than that of the canes diffused. The average ratio of the weight of the cane to that of the diffusion juice in the experiments was not far from 100: 125. It is true that in localities where coal can be obtained for $20 a car-load, a very dilute juice is not so objectionable, from a merely economical view. On the other hand, if the juice is first to be concentrated in open pans, its dilution becomes a very serious matter. The liability to inversion on long boiling is too well known to need any additional emphasis here. But there are many localities where coal is dear and evaporating capacity limited. In such places the production of a juice as dilute as that represented in the foregoing tables would be a fatal objection to the process.

I confess I do not see how such dense juices are obtained as those mentioned in the experiments in Guadaloupe. In quite a number of my experiments I allowed the water to remain ten minutes in contact with each cell of chips, or ninety minutes in all for the contents of each cell. Yet the highest specific gravity obtained even by this method was 1.0473. There are three factors in the problem of the application of diffusion to sorghum which demand a more careful study, viz, (*a*) time, (*b*) temperature, and (*c*) pressure.

(*a*) I think for nine cells two hours at a mean of 60° C. would not be more than sufficient to secure the mean density desired.

I am convinced now that I did not allow the diffusion juices to remain long enough in contact with the chips. The chief objection to allowing a longer time for diffusion is found in the tendency to fermentation, which these dilute juices possess in the highest degree. This objection I consider to be fully met by my uniform practice of introducing into each fresh charge of warm water some antiseptic like lime bisulphite, or carbolic acid. Another objection is found in the increased time required to complete the extraction. This, however, can be met by increasing the size of the diffusers.

(*b*) There is no doubt of the fact that osmosis in vegetable cells will take place more rapidly as the temperature of the ambient fluid rises. Thus a more rapid extraction of the sugar will take place if the temperature be kept at a higher degree. On the other hand, as water approaches a boiling point it dissolves any starch granules which the cells may contain, and transforms the insoluble pectose into soluble pectine, and brings into solution any other difficultly soluble bodies which the chips may contain. I have noticed, moreover, at these high temperatures, that the outflowing juice is highly colored and has a peculiar odor, which indicates the solution of some odoriferous bodies not dissolved by a colder liquid.

(*c*) This method works well, and has none of the disadvantages which characterize the others. I have noticed that when by means of a system of steam-pipes with which my battery was supplied I produced a pressure of two or three atmospheres for a few moments on each cell, the degree of exhaustion was much greater than when only the ordinary pressure of the water, amounting to less than two atmospheres, was employed. The sorghum cane is more compact than tropical cane, and will require more care in diffusion.

Respecting the success which attended the experiments the following statements may be made: †

The extraction of at least 85 per cent. of the total sugars present was secured. In many of the experiments, as will be seen by consulting the table, scarcely a trace of sugar could be detected in the exhausted chips.

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* *Op. cit.*, p. 34. † Bulletin No. 2, p. 36.

The production of a quantity of melada, represented by from 10.9 to 12.28 per cent. of the weight of the cane diffused.

This was secured with a cane in which the total sugars did not exceed 11.68 per cent. The percentage of melada by this process will be found just about equal to the per cent. of total sugars in the cane.

It ought to be greater with a more perfect extraction, but I am speaking only of results actually obtained. This yield is just about double that obtained by the large factories at Rio Grande, Champaign, and other places.

The production of a juice of great purity, which lends itself easily to processes of depuration.

I consider the experiments, however, to have their chief value in the fact that they will call the attention of cane-growers to the advantages which a rational system of diffusion will have over pressure in the extraction of the saccharine matter. I hope to be able at the end of another season to report further progress in this interesting problem.

In the present condition of the sorghum-sugar industry, in which it has alike to be protected from the overzeal of its friends and the opposition of its enemies, the process of diffusion offers the most promising outlook for success. It therefore seems the duty of this division to make a more practical test of this process and on a larger scale.

In the following year, in harmony with the recommendations of the bulletin, Congress made an appropriation to continue the work on a larger scale. This appropriation, however, was made so late in the year (viz, June, 1884) that it was quite impossible to accomplish anything in the line of work proposed. Unfortunately by the terms of the appropriation the Commissioner was led to believe that it could be used for purposes other than investigations in the manufacture of sugar, and hence little of it was left for the operations of the next year, or to be covered back into the Treasury. In this connection it would be proper to call attention to the fact that appropriations made for experiments in agriculture which are available only after June 30 of each year and which by the terms of the act cannot be carried forward to another fiscal year, are but poorly suited to attain the purpose proposed. Not only is this true of money voted to experiments in the manufacture of sugar, but to all agricultural operations. The experience of the chemical division for a number of years in this matter is so full of disasters due to the time of availability of appropriations that I beg leave to call your especial attention to this point, hoping that by representation of the facts to the Committees of the House and Senate on Agriculture you may be able to secure relief from this most serious fault. The agricultural fiscal year should either begin on January 1, or else the appropriations should remain available for at least eighteen months. It would be even better to leave the time during which such an appropriation is to be expended to the discretion of the Commissioner of Agriculture.

During 1885 the Department continued its investigations in the application of diffusion to cane, under many difficulties, but still with a certain degree of success.

A diffusion battery was erected at Ottawa, Kans., and operated long

enough to demonstrate both the success of the experiment and the defects of the machinery employed.

The results of the experiments were published in Bulletin No. 6. Following is a summary of these results:*

On Thursday, October 8, our first trial took place. The cutters were started at 8 a. m., and work was continued until 5 a. m., Friday, October 9. During this time 70 cells were diffused of 1,400 pounds each, or a total of 98,000 pounds. The weight of the diffused juice was 96,140 pounds from 65 cells.

The analysis of the exhausted chips showed only a trace of sucrose and 0.10 per cent. of glucose. The waste waters of diffusion showed a loss of 0.10 per cent. sucrose and 0.10 per cent. glucose. The total loss of sugars, therefore, was 0.10 per cent. of sucrose and 0.20 per cent. glucose. The excess of glucose in these analyses is explained by the fact that the samples of exhausted chips and waste waters taken during the night were not analyzed until the next day, and meanwhile the sucrose had suffered inversion.

The total loss of sugar, therefore, in chips and waste waters was .30 per cent. This is a remarkably good extraction, and the result is very satisfactory.

When the cells could be promptly emptied it was an easy matter to make a diffusion every twelve minutes, and the extraction was just as good as in those cases where twice that time was employed. These results showed that sorghum cane diffuses with great readiness, and in this respect it appears to have an advantage over the beet.

The cane employed was quite imperfectly stripped and the sheaths and remaining blades were, of course, treated in the cells together with the chips. The coloring and gummy matters which they contained were, therefore, found in the diffusion juices.

It will be a very easy matter to run these chips through a sieve in connection with a blower and remove all objectionable matter.

Following is a table showing the details of the diffusion:

Table of diffusion.

Number of cell.	Volume of juice drawn off.	Temperature of juice.	Temperature first preceding cell.	Temperature second preceding cell.	Specific gravity.	Time.
	Liters.	° C.	° C.	° C.		a. m.
1	700	22	60	77	1.050	9.35
2	700	19	61	75	1.031	9.44
3	700	24	72	64	1.038	9.47
4	700	20	60	64	1.040	10.13
5	700	19	62	59	1.041	10.25
6	700	24	.....	58	1.045	10.27
7	700	19	61	.....	1.045	10.39
8	700	25	60	58	1.042	10.51
9	700	27	58	60	1.042	11.20
10	700	27	59	58	1.041	11.37
11	700	29	64	56	1.041	11.50
						p. m.
12	700	24	.....	67	1.039	12.02
13†	700	24	60	52	1.039	12.14
14	700	27	50	56	1.026	1.25
15	700	25	.....	50	1.036	1.35
16	700	23	50	.....	1.037	1.47
17	700	23	54	50	1.038	1.58
18	700	25	49	55	1.037	2.10
19	700	27	52	53	1.037	2.22
20	700	25	.....	.....	1.035	2.34
21	700	22	58	.....	1.038	2.50
22	700	24	60	.....	1.037	3.02

* Bulletin No. 6, pp. 5, *et seq.*

† Stopped for dinner.

Table of diffusion—Continued.

Number of cell.	Volume of juice drawn off.	Temperature of juice.	Temperature first preceding cell.	Temperature second preceding cell.	Specific gravity.	Time.
	Liters.	° C.	° C.	° C.		a. m.
23	700	24	66	54	1.037	3.14
24	700	25	67	59	1.038	3.26
25	700	25	.....	56	1.039	3.41
26	700	26	64	.....	1.040	3.53
27	700	23	64	55	1.039	4.06
28	700	23	66	55	1.040	4.23
29	700	26	65	54	1.039	4.36
30	700	25	58	50	1.036	4.52
31	700	24	56	50	1.039	5.15
32	700	.....	64	56	1.039	5.27
33*	600	26	38	59	1.039	5.42
34	600	22	.....	.....	1.034	7.15
35	600	.....	38	59	.....	7.30
36	600	19	46	58	1.036	7.50
37	600	18	54	58	1.038	8.12
38	600	22	54	58	1.034	8.37
39	600	19	56	64	1.040	8.50
40	600	28	62	.....	1.040	9.00
41	600	21	65	56	1.041	10.05
42	600	24	65	56	1.042	10.19
43	600	23	.....	56	1.043	10.31
44	600	23	65	.....	1.042	10.47
45	600	27	64	54	1.041	11.09
46	600	30	68	56	1.040	11.20
47	600	26	68	56	1.040	11.37
48	600	24	68	56	1.040	11.59
						a. m.
49	600	23	64	58	1.042	12.48
50	600	24	68	.....	1.042	1.14
51	600	22	68	56	1.041	1.26
52	600	23	63	54	1.040	1.55
53	600	27	.....	58	1.039	2.17
54	600	24	66	.....	1.041	2.31
55	600	24	65	57	1.042	3.02
56	600	27	68	58	1.041	3.15
57	600	25	68	57	1.041	3.27
58	600	22	59	54	1.036	3.45
59	600	21	58	54	1.041	3.59
60	600	23	.....	55	1.042	4.13
61	600	61	67	62	1.042	4.28
62	600	20	67	62	1.042	4.40
63	600	19	.....	43	1.053	4.53

* Stopped for supper.

Two more portions of 600 liters each were drawn off, and the other five cells were then discarded.

In the first series of 32 cells 700 liters of juice were drawn off at each charge, or 1,540 pounds. Since the average charge of each cell was 1,400 pounds of chips, the ratio of diffusion juice to weight of cane was 110 : 100. In the second series of 31 cells 600 liters of juice were drawn off at each charge, or 1,320 pounds; the ratio of diffusion juice to weight of cane was 94.3 : 100. It appears from this that diffusion can be successfully practiced with sorghum cane when the weight of juice obtained is made about the same as that of the cane diffused. The mean specific gravity of the 32 charges of 700 liters each was 1.0394 at 25°, or at 15° 1.0411, corresponding to 10.24 per cent. total solids. The average of specific gravity of the juice of 32 charges of 600 liters each was 1.0405 at 25°, or 1.0424 at 15°, corresponding to 10.55 per cent. total solids. The cane varied so greatly in its composition that no estimate of the degree of extraction could be made from the analyses of the cane juices.

The following analyses were made of the diffusion juices during the day:

	First time, 10.30 a. m.	Second time, 3 p. m.
	Per cent.	*Per cent.*
Total solids	10.84	9.70
Glucose	2.32	2.00
Sucrose	6.19	5.90
Solids not sugar	2.33	1.80

No analyses of the diffusion juice were made at night.

Analyses were also made of the cane juice, expressed on small mill, from canes taken from the yard whence the cutter carriers were supplied.

	First analysis, 10 a. m.	Second analysis, 11 a. m.	Third analysis, 11.30 a. m.
	Per cent.	*Per cent.*	*Per cent.*
Total solids	17.00	15.60	15.20
Sucrose	11.24	9.62	9.83
Glucose	2.44	2.85	3.41
Not sugar	3.32	3.13	1.96

The samples taken for the above analyses showed how seriously the frost had affected the canes and how irregular they were in their composition. The peculiar odor characteristic of frosted sorghum was also very apparent in the chips as they came from the cutter. This condition of things rendered this part of the work very unsatisfactory.

The weight of coal used from the time of firing up on Thursday morning until the time of stopping Friday morning—nearly twenty-four hours—was a little over 3,000 pounds. But when the chips could be promptly removed from the cells it was possible to make a diffusion every ten minutes. Hence the whole work might have been done in seven hundred minutes, or eleven hours and forty minutes. In this case half the coal might have been saved.

The force required to do the work was:

One fireman (day) and one (night), at $1.50	$3 00
Four men on cane-carrier (day) and four (night), at $1.25	10 00
Four men at battery (day) and four (night), at $1.25	10 00
One team to remove chips (day) and one (night), at $2.50	5 00
One valve-man (day) and one (night), at $2.25	4 50
One and one-half tons coal, at $3.25	4 88
Oil and lights	1 00
One boy (to sweep, &c.)	75
Total cost of diffusing 49 tons of cane	$38 13

With slight changes in the battery it will be an easy matter to reduce this to $20, and if the cells are made twice as large the cost will be still less. With apparatus properly arranged the cost of diffusing a ton of cane will not be greater than 30 cents. Good machinists estimated that about 15 horse-power was used in driving the machinery and heating the cells in the experiments made.

A study of the table of diffusions reveals some curious facts relating to the variations in the composition of the cane. Beginning with the fourth diffusion and ending with the eleventh, eight cells in all, the following facts appear: The mean specific gravity of the diffusion juice at 15° was 1.045, corresponding to 11.2 per cent. total solids. The weight of juice drawn off was 10 per cent. greater than the weight of cane diffused; 11.2 total solids in 110 pounds would be equal to 12.32 total solids in

100 pounds. Add to this the .30 sugar lost in chips and water of diffusion and .15 not sugar, we obtain 12.77 as the total solids in cane diffused, calculated from the diffusion data. This would correspond to 14.05 total solids in the juice expressed by mill.

After the eleventh diffusion the cane rapidly deteriorated. The mean specific gravity from the eleventh to the thirty-third diffusion, was 10.39 (circa) at 15°, corresponding to 9.75 per cent. total solids. Proceeding as above, the following numbers are obtained: Total solids in cane diffused, 11.18 per cent. This would give for mill juice 12.35 per cent.

After the thirty-second diffusion the weight of juice drawn off was 5 per cent. less than weight of cane diffused. The specific gravity of the diffusion juice at 15° was 1.044 (circa), corresponding to 11 per cent. total solids. Diminishing this by 5 per cent. and adding .45 we obtain 11 as total solids in cane, or 12.10 per cent. total solids in expressed juice.

Unfortunately the carbonatation pump broke after one-third of the juice had been defecated. A careful estimate of the number of tons of juice worked, showed that the juice from 15 tons of cane had been carbonated.

This yielded 4,320 pounds of *masse cuite*, containing 76.9 per cent. solid matter, or 11 per cent. (nearly) on weight of cane worked.

The composition of this *masse cuite* is shown by the following analysis:

	Per cent.
Sucrose	53.48
Glucose	13.55
Water	23.10
Ash	4.74
Not sugar	5.13

This *masse cuite* was allowed to stand in cars (it was not boiled to grain) one week and was then swung out, yielding 1,420 pounds, or nearly 33 per cent., of washed and dried sugar, or 95 pounds per ton of cane worked.

Allowing 12 pounds per gallon for the *masse cuite* the number of gallons per ton of cane was 24.

The sugar was of fine quality, the molasses of much better quality than that obtained in the usual way, and the whole product was in every respect satisfactory.

CARBONATATION.

* As pointed out in the experiments in carbonatation described in Bulletin No. 3, it is evident that the process so long and so successfully practiced with beet juices is also capable of giving good results with cane juices. The process is a very simple one, and consists in adding to the diffusion or expressed juice a large excess of lime and afterwards precipating the greater part of it with carbonic acid. The whole is then sent to the filter press, where the precipitated carbonate of lime and impurities are separated from the juice.

I had not expected to make a trial of this process, on account of the fact that I feared the appropriation would not be sufficient to carry out both experiments. On arriving here, however, I learned that the sugar company had two filter presses and air-pump and two pans which could be arranged so as to give the process a trial on a large scale. Accordingly I had a furnace constructed for furnishing carbonic acid and the rest of the apparatus put into shape for the experiments. The furnace was designed by Mr. G. L. Spencer, who also had a general supervision of the entire work.

Our former experiments had shown that the process had to be carried on somewhat differently from that of the beet juices, owing to the presence in sorghum juice of a large percentage of glucose.

* Bulletin No. 6, pp. 13 *et seq.*

Our first experiments were made with the diffusion juices obtained Thursday, October 8. At that time the effects of the frost had not shown themselves to any great extent. It was found that about 1½ per cent. of CaO (lime) was sufficient to produce a perfect defecation of the juice. On that day, as nearly as we could estimate it, about 40,000 pounds of juice were carbonatated, with the most gratifying results. The juice came from the filter press perfectly limpid and of a delicate amber color. After passing though a sulphur box this juice was sent to the evaporators and reduced to a *masse cuite*, which in color, purity and taste was greatly superior to the best product obtained by the usual method. Unfortunately our improvised air-pump broke down in the midst of the work, which caused the loss of more than half of the diffusion juice obtained which had already been limed for carbonatation.

The carbonatation of sorghum juice, however, demands the greatest care. If too little lime is added the precipitate does not settle readily and filtration is slow and imperfect. The carbonatation must be continued until all but about .02 per cent. of the lime has been removed. If more than this remains the juice will darken up and become bitter on boiling. If less than this quantity is left the impurities appear to be redissolved, and a green scum forms on top of the still liquor instead of sinking with the precipitate. With the help of proper test reagents a little experience will enable the operator to carry the carbonatation to a successful completion.

It is found also that the temperature during carbonatation should not be allowed to rise above 40° C. Directly the carbonatation is completed the juice is raised as rapidly as possible to the boiling point and sent at once to the filter press. If allowed to stand the liquor will quickly darken. Foaming is prevented by the addition of a little lard and by jets of steam from a perforated pipe near the top of the pan.

Analysis of carbonatated juices.

	Sucrose.	Glucose.	Not sugars.	Total solids.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1	5.25	1.18	2.25	8.68
2	6.51	1.47	3.00	10.98
3	4.99	0.48	3.72	9.19

The first and second of these represent successful carbonatation. The filtered juice was all that could be desired in color and flavor. The *masse cuite* made from it was also of the best quality as has already been noted.

The third analysis represents an unsuccessful carbonatation. Too much lime was left in the liquor, and the *masse cuite* was black and bitter.

In all about 100,000 pounds of juice was carbonatated, and I do not hesitate to say that this process of defecation offers every evidence of being the one which should be brought into general use. In large sugar factories the saving in scums alone in one season would pay for the carbonatation plant.

GENERAL CONCLUSIONS.

The general results of the experiments may be summarized as follows:*

(1) By the process of diffusion 98† per cent. of the sugar in the cane was extracted, and the yield was fully double that obtained in the ordinary way.

(2) The difficulties to be overcome in the application of diffusion are wholly mechanical. With the apparatus on hand the following changes are necessary in order to be able to work 120 tons per day: (*a*) The diffusion cells should be made twice as large as they now are; that is, of 130 cubic feet capacity. (*b*) The opening through which the chips are discharged should be made as nearly as possible of the same area as

* Bulletin No. 6, pp. 19 *et seq.*

† For cane containing 13 per cent. sugars.

a horizontal cross-section of the cell. (*c*) The forced feed of the cutters requires a few minor changes in order to prevent choking. (*d*) The apparatus for delivering the chips to the cells should be remodeled so as to dispense with the labor of one man.

(3) The process of carbonatation for the purification of the juice is the only method which will give a limpid juice with a minimum of waste and a maximum of purity.

(4) By a proper combination of diffusion and carbonatation the experiments have demonstrated that fully 95 per cent. of the sugar in the cane can be placed on the market either as dry sugar or molasses.

(5) It is highly important that the Department complete the experiments so successfully inaugurated by making the changes in the machinery mentioned above and by the erection of a complete carbonatation outfit.

One of the most important of the facts demonstrated by the Ottawa experiments was to point out the defects of the apparatus employed, defects due solely to a hurried and random construction of the machinery, for which the contractors were in no sense responsible. Unfortunately all the weak points of the apparatus had been duplicated in a plant which it was expected would be tried in Louisiana in November, 1885. On my appeal to you to postpone a series of experiments, which on account of mechanical difficulties could not have failed to prejudice the Louisiana planters against a process which most certainly, properly applied, promises them great relief, you very promptly and very wisely, in the opinion of all competent critics, ordered the further prosecution of the work to be suspended.

With this unstudied attempt to introduce diffusion into Louisiana I feel quite sure we have reached the end of expensive and ill-considered experiments.

Directly the experiments were finished in Kansas I received from you the following instructions:

WASHINGTON, D. C., *November* 9, 1885.

SIR: You are hereby directed, in the further prosecution of the experiments for the production of sugar, to proceed to Europe for the purpose of inspecting and purchasing such forms of machinery as may appear most useful for the purpose named, and to gather such information in respect of the sugar industry as may be calculated to secure the greatest success in the work which the Department has undertaken.

NORMAN J. COLMAN,
Commissioner.

Dr. H. W. WILEY,
Chemist.

Although I had had no time to rest from the fatigue of the exceedingly arduous duties of directing the experiments in Kansas, I hastened to enter on a plan of investigation, which, had it been pursued from the first, would have ere this secured the complete success of the effort of the Department to establish the process of diffusion on a successful working scale.

As will be seen by referring to the résumé of the work at Ottawa the chief mechanical difficulty to be overcome was in respect of the method for securing the removal of the exhausted chips from the cells.

I was fortunate at the very beginning of the investigations in being

able to see in operation a diffusion battery in which the discharge gate was at the bottom "and of superficial area equal to the longest horizontal cross-section of the cell."

THE SUGAR FACTORY AT ABBEVILLE, FRANCE.

The location of the central factory at Abbeville and of the several bascules* and raperies† connected with it is shown by the map, Fig. 1.

I visited two raperies of the Abbeville factory, viz., the one near the works and the one at Crecy. The only difference in these batteries is one of capacity and in the arrangement by which the battery at Crecy is provided with compressed air for driving the water out of the cell before the chips are removed. The central factory at Abbeville in all has five raperies connected with it.

These five raperies are capable of working 1,000 tons of beets per day. They are situated at the following distances from the central factory:

Raperie d'Abbeville	meters	250
Raperie de Crecy	kilometers	16
Raperie de Martainsville	do	14
Raperie de Quesnoy	do	10
Raperie de St. Requier	do	8

Each of these raperies is connected with the central works by a pipe line. The pipe is about half a meter below the surface, following the undulations of the soil, and the juice is forced to the central works by a pump at each factory. In addition to these five raperies the central factory possesses fourteen stations (bascules), for the reception of beets. In all five hundred and forty persons are employed in securing beets, placing them in silos, and delivering them to the different raperies. All the stations are connected with each other and with the central factory by telegraph.

METHOD OF RECEIVING THE BEETS.

Before giving the details of the operations of the bascule it will be well to notice some points of the law relating to the tax on beets used for making sugar. Until the summer of 1884 the tax was laid directly on the weight of sugar produced. This method of taxation made it useless for the manufacturer to get the maximum yield from a given quantity of beets, because he soon reached a point in the operation where the additional sugar obtained did not more than pay the tax laid on it. It was better for him therefore to begin on a fresh quantity of beets than to try to get the last of the sugar from the beets and the molasses. This induced the cultivator of beets to supply the demand for quantity rather than quality. Hence the French farmer raised a greater

* Bascule, station where beets are received and weighed.

† Raperie, station where sugar is extracted from the beet.

weight of beets to the hectare than his German neighbor, but with less saccharine strength. In 1884 the law was changed and modeled after the German method of taxation, *i. e.*, imposing the tax directly on the weight of beets entering into the factory. This changed the entire aspect of affairs. The manufacturers now wanted rich beets and wanted also to get all the sugar out of them possible. It has often been said that legislation did not affect agriculture, but here, at least, is one case where it did. The director of the central factory told me that already there had been a marked increase in the richness of the beet since the new law went into effect. As is well known the sugar content of the beet is increased by the use of chemical manures and by planting them nearer together, so as to prevent them growing to a large size. Beets grown ten to the square meter are smaller and richer than those grown six to the square meter. But the French farmer, independent in the possession of his own farm and team, is, like all land proprietors, most decidely conservative. He is slow to adapt himself to the changed conditions which the new legislation has brought about him. Many of them still continue to grow the big beets with the lower saccharine strength, requiring, as it does, much less labor and expense than for the small and rich kind. Hence the buyers are compelled to purchase the beets by two different methods, viz: at a fixed price for the conservative farmers, who do not want to alter the old methods of beet culture, and according to richness for the more progressive ones who have accepted the new order of things.

BASE PRICE BY WEIGHT.

The base price for the present is fixed at 20 francs per ton of 1,000 kilograms, or 2,200 pounds. But a premium of 2 francs per 1,000 kilograms is accorded to those who grow eight to nine beets per square meter; to those who grow nine to ten beets per square meter 3 francs per 1,000 kilograms; to those who grow ten and over per square meter 4 francs per 1,000 kilograms.

The counting of the plants takes place after the 15th of August and according to a plan agreed upon by manufacturer and producer.

PRICE BY DENSITY.

The base price is fixed, for a juice of 6° B. density, at 22 francs per 1,000 kilograms. For every one-tenth of a degree above 6° there is an increase of price of 1 franc per 1,000 kilograms, and a decrease of 1 franc for each tenth of a degree below 6°. Thus there is the greatest incentive to the grower to produce a beet whose juice, for instance, would have a density of 7° for which he would receive 32 francs per 1,000 kilograms. This degree of richness is not hard to attain. If the density falls below 5.5° a special arrangement is made. Manufacturers are not anxious to buy so poor a beet.

TAKING THE DENSITY.

The density is taken at the bascule. By agreement the farmers are to deliver their beets in thirds, one-third in October, one in November, and one in December. Thus the overcrowding of the bascule is prevented. For those which are delivered in December the farmer receives 2 francs per 1,000 kilograms for expense of ensilage.

A certain number of beets are taken from each load brought by a given farmer until 20 kilograms are selected. After weighing they are given to some women who carefully clean them and remove any imperfect part. They are then weighed and the loss gives weight due to dirt, &c. The percentage of loss is then calculated and the net weight of the beets delivered is thus obtained. All payments are made on the net weight. It seems that bribery may sometimes creep into agriculture, since several farmers have been detected in bribing the women to do the work of cleaning less perfectly. They want the same price for their soil as for their beets, and when the value of the land here is taken into account the desire does not seem altogether unreasonable. After cleaning and weighing, a part of the sample is taken, including an equal number of large, medium, and small beets. These are cut into quarters, and one-quarter of each taken for the experiment. After rasping and expression the juice is place in a decanting cylinder with a stop-cock at about one-third of the distance from bottom to top. After standing twenty minutes the dirt has all subsided and the bubbles have risen to the surface. The clear juice is now drawn off into another cylinder, and its density and temperature taken. The density is then reduced to a constant temperature of 15° C. In this way an accurate and therefore satisfactory determination is made. In all, seven or eight persons are constantly employed at each bascule. The bascules are either near the raperies or connected with them by railway.

From the bascules the beets are taken either directly to the raperie or placed in silos to preserve them from the frost. Since even in Northern France the degree of cold in the winter is not very great, a light covering of straw and earth is sufficient to protect them. These silos are not pits, but the beets are placed in piles on the surface of the soil. These piles have a base 3 meters wide. They are 1.8 meters high and have a width at the top of 2.6 meters. They are placed in parallel rows, and are conveniently arranged for the access of the carts which are to convey them to the raperies.

The total weight of beets used by the central factory amounts to 80,000,000 kilograms annually. These are grown on 3,100 hectacres of land. The mean yield per hectare is about 25,000 kilograms.

MACHINERY AT THE CENTRAL FACTORY.

No beets whatever are received at the central factory. It is devoted solely to the working of the juices delivered to it by the pipe lines from the various raperies.

The general plan of the saturation tanks, vacuum pans, &c., is shown by Fig. 2.

There are twelve boilers of 160 square meters surface.

For the first carbonatation of the juice there are four pans each of 210 hectoliters* capacity. These are covered and furnished in addition to the pipe for delivering the CO_2, with copper steam pipes and a revolving beater to keep down the foam. The second carbonatation has two tanks of similar capacity and fixtures. Sixteen filter presses are in use, of which eleven are used for the first carbonatation, four for the second, and one for the extraction of the sugar from the cakes, which for this purpose are beaten up to a thick cream with hot water and then sent to the press.

The juice is also passed through long bag filters, of which there are three sets of six bags each for the juice of the second carbonatation and two sets of same capacity for the sirups. By the use of these filters and careful attention to the corbonatation the use of bone-black has been entirely suppressed.

The triple effect pans, which can also be used as a double effect, have 1,500 square meters of surface.

The strike pans are two in number, each with a capacity of 280 hectoliters. The *masse cuite* falls into two tanks, each of 240 hectoliters capacity.

The second and third sugars are placed in vats for crystallization, the total capacity of which amounts to 3,100 hectoliters.

The second and third sugars are boiled in a separate strike pan, of 100 hectoliters capacity.

Twelve thousand hectoliters of diffusion juice are worked every twenty-four hours, producing 500 sacks of first sugar of 100 kilograms each, or a total of 50,000 kilograms of white sugar a day. This sugar polarizes from 98°.7 to 99°. Nineteen centrifugals are constantly in use for first sugars. The general arrangement of the engines, pumps, carbonatators, triple effects, and strike pans, is shown in Fig. 2.

The second sugars are allowed to stand three or four weeks in the tanks, with the temperature kept at 35° to 40° C., before being passed through the centrifugals; and the third sugars usually are left until the manufacturing season is over. Each of these sugars polarizes from 90° to 92°. The molasses from the third sugars is passed through the osmogenes, of which there are 28, each one with 100 chambers, constructed according to the system of Dubrunfaut. The sugar obtained by this treatment has the same opticity as that of the second and third products.

The mean annual production of the factory is 45,000 sacks of first sugar and 25,000 sacks of all other kinds, or a total 7,000,000 kilograms.

The limekiln has a capacity of 300 cubic meters. About 10 per cent. of coke is mixed with the limestone, and this furnishes sufficient fuel to

* One hectoliter = 100 liters = about 25 gallons.

keep the furnace working. Hence, it is not necessary to use the lateral furnaces at the bottom except at the beginning of the campaign.

The whole apparatus of the factory is so admirably arranged that the consumption of coal per 1,000 kilograms of beets is only 110 to 115 kilograms.

The diffusion plants at the several raperies have the following capacities:

At Abbeville 12 cells, each of 30 hectoliters capacity.

At Martainsville 12 cells, each of 25 hectoliters capacity.

At Crecy 12 cells, each of 20 hectoliters capacity.

At Quesnoy 12 cells, each of 20 hectoliters capacity.

At St. Requier a continuous diffuser, system Perret, is employed.

The mean loss of sugar in waters and exhausted chips is 0.25 per cent. The mean density of the diffusion juice is 1.0425.

The juice as it comes from the several raperies is received in a large tank of 2,750 hectoliters capacity. At present three of the pipe lines coalesce and enter the tank by a common duct. The other two enter by their own pipes. In order that a chemical control of the juice from each factory may be made at the central office it is the intention of the manager, after this season, to have the juice from each raperie brought to the receiving tank by a separate pipe.

The quantity of beets worked during the campaign of 1884–'85 amounted to 87,626,632 kilograms.

The expenses of the campaign (part of the season bone-black was used) were as follows:

	Francs.
Beets	1,924,653.26
Coal (9,650,000 kilograms)	217,982.48
Limekiln (including coke, 834,220 kilograms and 10,322 cubic meters limestone)	77,332.10
Bone-black (a part of the season, after which its use was abandoned)	9,227.91
Light (mostly electric lighting)	27,319.75
Lubricants	10,557.04
Towels, filter cloths, &c	10,140.07
Sacks for sugar	25,728.35
Labor	170,648.13
Total	2,473,589.09

	Kilograms.
Sugar made	5,490,000

For these facts concerning the operations of this factory I am indebted to M. Mennesson, the efficient and energetic manager of the company, under whose directions this factory has made handsome dividends even during the general depression of the sugar industry which has driven so many of the European factories into bankruptcy. When I left Paris (January 19, 1886) I was told that in the present campaign, just then closing, the company had been more successful than last year.

I have presented somewhat in detail the workings of this factory, because I was greatly impressed with the fact that with such a central

factory for treating the juices, it would be possible in Louisiana and other sugar-producing localities to greatly decrease the cost of manufacture by concentrating the costly machinery necessary to sugar manufacture, and making it of a capacity large enough to handle the juice of all the cane grown in its vicinity.

The transmission of the juice by a pipe line is certainly the most economical method of transportation that can be devised. The first cost of the line is not great, and the expense of forcing the juice through it very slight.

The apparatus used at the raperies consists only of the diffusion battery, and the building to protect it can be of the most inexpensive kind. For $25,000 a battery and building could be erected capable of treating 150 to 200 tons of cane a day. From six to ten of these could be connected with a central factory of the most approved construction. It will be easy for practical sugar makers, who know the expense of putting up the triple and double effect, and strike pans and other apparatus necessary to sugar making, to understand what an enormous saving of money, fuel, and labor there would be in having in one compact form the apparatus capable of working the juice from a thousand tons of cane a day, over the erection of eight or ten similar plants, each having a capacity of only 100 to 150 tons.

It is true that such a central factory would require superior management. The conduct of such an establishment should be as exceptional as the apparatus itself. It is true also that any fault of management in such a central factory would prove proportionately far more disastrous than in a smaller concern. These are objections to the establishment of a central factory, but not arguments against it.

If the march of events, as is probable, should render necessary the reconstruction of the sugar factories of our country I certainly hope that a sufficient number of progressive and energetic manufacturers may be found to establish such a system in the United States. Properly conducted it would have the brightest promise of success.

THE WORKING OF THE BATTERIES AT ABBEVILLE AND CRECY.

The immediate object of my study was the method of working the cells of the battery. Since the mechanical construction of these cells is almost identical with that of the battery at Almeria, the more minute description of them will be deferred to the section devoted to that battery.

Arrangement of the cells.—A view of one of the cells of the Abbeville battery, with its connections, is given in Fig. 3.

Both at Abbeville and Crecy, as well as at Almeria, the cells of the battery are arranged in the form of a circle. There are three chief advantages of this method over the old one of disposition in single or double line. First of all, the charging of the cells takes place much more readily with a circular arrangement. In all batteries disposed

for working beets the cutter is placed above the cells. It is more convenient to elevate the beets by suitable apparatus than it would be to carry the chips to the proper altitude. In all circular batteries the cutter is placed immediately over the center of the battery. The chips fall into the upper expansion of a pivoted chute which is placed at an angle of about 40 degrees. With this inclination the chips fall readily down the chute and into the opening of the cell.

The bottom of the chute is furnished with a hinged nozzle which, on being raised, arrests the discharge of the chips until the chute is pushed to the next cell, a procedure which takes only a moment of time. Thus the filling of each cell is entirely automatic, and the arrangement is the most simple as well as the most effective possible. Usually the cutter has a capacity greater than the battery, so that often its operation is stopped while the feed channel is changed from one cell to the next. It can be done, however, very well with the cutter in motion.

In the second place, the circular disposition allows the exhausted chips to fall into a common pit, whence they are easily removed by an elevator to the presses. This pit, circular in form, is furnished with a bottom sloping toward the center, over which the chips readily move when discharged from the cells. Very little manual labor is therefore required to convey them to the elevator.

Lastly, the circular disposition permits the apparatus to be put up in a much more compact form, and thus diminishes the cost of the building and other necessary fixtures. There are many minor points of advantage, and in the erection of new plants at the present time the disposition of the cells in a circle is almost always preferred. The general view of the circular disposition, showing the method of charging and giving a notion of the arrangement of the necessary apparatus is given in Fig. 4.

The general disposition of the batteries at Abbeville and Crecy, although admirable, does not at present demand further attention. The point of greatest interest to the present investigations is the arrangement of the lower opening or discharge gate. By making this gate of the same area (nearly) as the horizontal cross-section of the cell, the discharge of the exhausted chips is secured directly the gate is opened and without any of the vexatious delay and labor with which we were so familiar at Ottawa, and to which all batteries with lateral discharge gates are more or less obnoxious.

It might be suggested that, with so large a gate, the difficulty of securing a tight joint would be so great as to prevent its practical use. This objection would indeed be a weighty one were it attempted to secure the joint by means of a rubber gasket in the usual way. But this is not attempted, and a perfect joint is secured by a device as simple as it is ingenious.

Hydraulic closure.—This device may be described as follows: In the lower edge of the cell a groove is cast in the form of a circular tube, the

interior of which is exposed on its lower border by planing away the wall of the tube until the opening is equal to one-half of the interior diameter. Into this canal is forced a thick rubber tube, which, on entering, nicely fills the cavity. The part of the tube lying in the exposed part of the canal slightly protrudes through the opening. This rubber circular tube is provided with a lateral opening, by means of which it can be connected with a water supply, the pressure of which is somewhat greater than that which produces the circulation of the liquid in the cells. A section of the rubber tube showing the lateral opening through which the pressure is supplied is shown in Fig. 5.

A section of this tube in position is also seen in Fig. 6 *a a*. When the gate is closed the projecting portion of the rubber tube is pressed against the flat surface of the rim of the gate, producing a joint which is perfectly tight, and which cannot get out of order. On account of the great elasticity of this tube, it happens that even if fragments of chips are left on the surface of contact the joint is formed over them with the same perfection as on the smooth iron. The water pressure, once applied, remains constantly on the tubes, whether the gates be open or shut. It is conveniently applied by connecting the opening *b*, Fig. 5, with a small tube joined to the pipe delivering the water to the tanks which supply the battery.

The working of this joint is so perfect, and it is so easily applied, that it is certainly destined to remove at an early day the prejudice against large gates and to make their use more general.

FURTHER DETAILS OF THE CONSTRUCTION OF THE CELL.

The further construction of the cells will be best understood by a simple diagram, showing the outlines of a cell suitable for work with either cane or beet chips. This is shown in Fig. 6.

In *a a* are shown sections of the tube for hydraulic closure, already described.

The cast-iron jacket attached to the lower part of the cell, and designed to support the machinery for opening and closing the gate, and furnish the outlet of the juice as it passes to the next cell or to the receiving tank without, is shown in section at *f f*. Inside of this, and extending up to join the cast-iron top of the cell, are seen the cell walls *c c c c*, made of thin boiler iron, in two sections, riveted together at *d d*. The hinged bottom of the cell consists of the perforated iron plate *l l*, which, when the gate is closed, forms a loose joint with the edge of the cell walls *c c*. This joint permits the liquid to pass, but is close enough to prevent the chips from passing into the ante-chambers of the exit tube. This perforated plate is held in position and joined to the other parts of the gate by the supports *g g g*. The framework of the gate is made of the wrought-iron plates *h h h h h' h'*, so adjusted as to give it strength and inflexibility. As the liquid is forced out of the cell it is stopped by the part of the gate *h' h'* forming the joint with the hy-

draulic tube, and thence finds its way to the exit pipe A. That part of the lower cell walls extending from the bottom to the point of attachment of the cast-iron jacket *f f* is also perforated, an arrangement which permits a more ready circulation of the fluids within the cells. It will be apparent at once, however, that those portions of the cell's liquid contents passing directly through these lateral perforations to the exit tube fail to traverse a portion of the contained chips, and to this extent the exhaustion of the chips in the lowest part of the cell may not be as perfect as in the upper portions. If the perforations in the plate *l l* are sufficiently numerous and large to secure a free movement of the liquid, I fail to see the necessity of these lateral perforations.

In the opinion of the makers of the cell, however, these lateral openings are necessary to secure a prompt and easy movement of the liquid from cell to cell, an opinion with which I am unable to agree. It is hardly necessary to say that the space inclosed by the plates *h h h h h' h'* is filled only with air.

An attachment to the gate, not shown in Fig. 6, but seen in Fig. 3, is the counter-weight which renders the manipulation of the door easy. This counter-weight is attached in the prolongation of the line joining the fastening of the door with the center of the hinge. It is a mass of cast iron contained in a wrought-iron frame, and is placed at such a distance as to slightly more than counterpoise the weight of the door. Thus, although the door is of a massive structure and very heavy, it is opened and closed in the most ready manner. As the door is opened the weight of chips throws it down. As soon as they are discharged the counterpoise tends to close it again. Thus one man, and even a boy, can easily open and close the gates. Both at Abbeville and Crecy the opening and closing of the gate are accomplished from the top. Thus the disagreeable necessity of keeping a laborer to open and close the gate constantly in the presence of the discharged chips and waste waters is avoided.

In the Abbeville battery the last charge of liquid is driven out of the cell next to be emptied by the usual method of displacing it with fresh water. Thus with each discharge of a cell a volume of waste water equal to the total capacity of the cell less the volume occupied by the chips is poured into the receiving pit. This procedure has several disadvantages: First of all there is a considerable loss of sugar in these waste waters; in the second place there is a great waste of water; and, last of all, this water is discharged where it is least wanted, *i. e.*, with the chips. To avoid these disadvantages the battery at Crecy is provided with an apparatus by means of which the last charge of liquid from the cell next to be emptied is removed by means of compressed air. This method, as I observed, succeeds most admirably, preventing at the same time both loss of sugar and waste of water.

The machinery by which this desirable result is accomplished is not complicated. A small air compressor is driven by a belt from the main shaft of the machinery. A very small expenditure of power is required to keep this compressor in motion. The compressed air is received into a closed tank of 15 to 20 hectoliters capacity, whence it is conveyed by iron pipes to the diffusion cells.

When a vessel is to be emptied the compressed air is admitted at the top and the pressure continued until the liquid is nearly all forced out. Care must be taken not to allow the pressure of the air to continue long enough to allow it to escape into the next vessel. The presence of air in the vessels or pipes interferes very seriously with the even flow of the liquids through the cells. When the cell is nearly full of air the communication with the air reservoir is closed and a valve opened to allow the compressed air in the cell to escape. It would be inconvenient to work the levers which open the gate with the air pressure still in action, and the remaining small portion of water in the cell would be ejected with great violence through the openings made as the fastenings are loosed. This water would be thrown in a horizontal direction to a great distance, and occasion considerable discomfort to the workmen and damage to surrounding objects.

After the pressure has been removed and the gate opened the whole mass of chips drops out with the greatest ease. It is easy, however, to see that the plan of using compressed air could not be adopted with any system of cell employing lateral discharge gates. No difference what the size of such gates might be, the automatic emptying of the cell can only take place by allowing the whole of the water to flow out with the chips. The same is true, but to a less extent, with floor discharge gates, which are distinctly smaller in area than the cross-section of the cell. But with such a gate as has been described, the cell full of exhausted beet or cane chips is discharged at once, and without the slightest difficulty. Having studied carefully both the wet and dry methods of discharge, I cannot express too strongly my opinion that the latter plan has many and important advantages over the former. Since its adoption will be attended with only a small additional expense, it will soon come into general use with all batteries whose discharge gates are suited to its use. The time required for each diffusion at Abbeville and Crecy is from six to eight minutes. By this rapid working, even with small cells, it is possible to secure the consumption of 200 tons per day. Experience has shown the European manufacturers that small batteries, that is those whose cells hold about 1,000 kilograms of chips, work more satisfactorily than the large ones. Hence the manufacture of batteries and cells that would hold two or three times this quantity of chips has been abandoned.

The temperature of the liquid in the cells is kept at 75° to 80° C. Instead of using ordinary thermometers, the calorisators are furnished with an indicator of temperature similar to a steam gauge. By this

plan not only is the great danger of breakage avoided, but the attendant is able to see at a glance and from a distance the temperature of each heater. Two men and a boy were employed to conduct the operations of the battery. The chief workman stood on the outside row of stop-cocks and levers and controlled the flow of the liquid in the diffusers, manipulated the cocks admitting the compressed air, and worked the screw which opened and closed the discharge gates. The second man was placed at the inside circle of control, and had immediate charge of the steam-cocks to the calorisators and the lever which fastened the discharge when closed. The boy was employed chiefly with keeping the polished pieces of the apparatus bright and in attending to any accidental matter that arose. By a slight change in the arrangement of the calorisator valves the constructors of the apparatus will, in future plants, bring them under the control of the chief of manipulation. With such a simple and inexpensive manipulation, the incentive which has led to the construction of several forms of continuous diffusion apparatus no longer exists.

I was exceedingly anxious to see a continuous diffuser in operation, but while at Abbeville I did not know that such an apparatus was in use at St. Requier, only a few kilometers distant. Afterwards I had no opportunity to see one at work. I was told that three such machines were in use during the season. The inquiries which I made concerning the operations of the one at St. Requier elicited no definite responses. But one fact appears, and that is that such an apparatus does work and gives reasonably good satisfaction. Otherwise the Abbeville company would not continue to employ it. I also learned that the extraction by continuous diffusion is not as close as in the ordinary way, a fact which clearly appears also in the analyses given in Bulletin No. 5, p. 111. I had an interview with the inventor of the apparatus, M. Perret, who endeavored to arrange for a visit to a battery in use, but before he could do so I was called to Germany to study the action of a cane-slicer.

While, therefore, the possibility of successful diffusion by the continuous process appears to be clearly established, the cheap and simple working of an ordinary battery of the form I have described leaves little cause to ask for a better way.

CANE-CUTTERS.

The cane-cutters used by the department at Ottawa were constructed by the Pusey and Jones Company, of Wilmington, Del. Two objects were kept in view in the construction of the cutters. The first was, of course, that the chips should be of a form favorable to rapid and thorough exhaustion. To avoid the delay incident to changing the knives, it was also decided to make the cutters in duplicate, and to have each of them of sufficient capacity to supply the battery. Thus while one was in use the knives of the other could be removed, ground, and re-

placed and no time be lost. Both objects were accomplished with encouraging success. Each of the cutters was able to furnish a ton of chips every ten or twelve minutes, and thus the capacity desired, viz, 6 tons per hour, was reached. When, however, the cutters were crowded to their full capacity there was a tendency for the forced feeding arrangement to become choked, a fault which a slight alteration of this part of the machinery will readily remove. In respect of the second object, viz, to obtain a chip suitable to rapid and complete exhaustion, perfect success was obtained. The chips were 2 to 3 millimeters in thickness, and by a peculiar form of the knives their surfaces were nicely grooved. By this means the packing of the chips by the approximation of smooth surfaces was entirely prevented. No matter how compactly the chips were placed in the cell, the free circulation of the diffusion liquids was not prevented. The grooving of the chips, as has already been indicated, was accomplished by grooving the face of the knife presented to the cane. These grooves were 8 millimeters wide, and in the center 2 millimeters deep. The groove extended back two-thirds of the breadth of the knife. The knife itself, made of the best steel, was 51 centimeters long, 14 centimeters wide, and 9 millimeters thick. On account of its being so hard to grind, I would recommend that the half of the knife turned from the cane be made of iron. The general appearance of the knife is shown in Fig. 7. There is one serious objection to a knife of this kind, viz, the ungrooved part of the edge does the chief part of the cutting, and hence grows dull quicker than a straight linear edge would do. It appeared necessary to regrind the knives after four or five hours of use.

CUTTING DISK.

The cutting disk was of cast iron, 82 inches in diameter, placed vertically, and having eight slits for the reception of the knives. The general arrangement of the disk with the apparatus for the forced feed and the knife in position is shown in Fig. 8.

The knives were fastened directly to a seat in the disk, each one by four bolts. This arrangement was entirely successful in holding the knives in position, but by reason of the trouble of changing the knives it would be much better to adopt some form of knife carrier which would permit the removal and insertion of a knife without delay. Such a device is used with admirable success in the cutter of the Sangerhäuser Company, which will be described further on. The rate of motion of the disk was two hundred per minute, a speed which I think is too great to secure symmetrical chips. I noticed always that those chips which were cut before the disk attained its maximum speed were more uniform in appearance than afterwards. The force with which the chips were thrown into the hopper when the disk was moving at its maximum speed was sufficient to split and break them. This, however, produced no loss of juice, and I doubt whether they, for this reason, were any

the less suited to the process of diffusion. The cutters were admirably built by the Pusey and Jones Company, and much of the success which attended their use was due to the mechanical excellence of the machinery.

The radical fault of such a cutter is found in the fact that it can be fed only at one point. Each knife must make an entire revolution to make a single cut. The force required to drive the knives through the canes is very small, and therefore if it could be conveniently arranged there would be great advantage in presenting several bundles of cane to each knife in a single revolution. It is at once manifest that such a multiple feed is quite impossible with a disk placed vertically.

HORIZONTAL DISK.

I was therefore much gratified to learn that the Sangerhäuser Maschinenfabrik, of Sangerhausen, Germany, had constructed a cutter with a horizontal disk with the express purpose of supplying the multiple feed.

A cutter constructed on the same principle by the Sudenburg Manufacturing Company had before this been tried in Java with excellent results, as will be seen in the report of the Java experiments given further on. The Sangerhäuser Company having imported some cane from Brazil invited me to attend a trial of their machine.

The machine employed was only about half the size of the one given in Fig. 8 *bis*, but was constructed on precisely the same plan.

I accordingly went to Sangerhausen, where I examined carefully the structure of the machine, and saw it in actual operation.

In Fig. 8 *bis* (1) is shown a general view of the cutter in position. In Fig. 8 *bis* (2) is presented a section through the center of the machine showing the arrangement of the driving machinery. In Fig. 8 *bis* (3) is found a view of the cutting disk from above. The hoppers, of which there are six, are placed at an angle of about 45 degrees. The cane is fed from the top resting on a roller on the upper edge of the hopper, which facilitates its progress to the knives. The canes are fed to the knives by the force of gravity alone. The knives are six in number, and are fixed in carriers that fit into a slot in the disk. This slot is larger near the center of the disk, and into this larger portion the knife carrier is placed through the opening shown in the figure. They are then pushed along a groove into their proper position (the narrower and external part of the slot), and are securely held there by centrifugal force. This method of securing the knives is extremely ingenious and effective, and permits all the knives to be taken out and new ones inserted in two or three minutes. Thus the necessity of having a duplicate cutter is avoided; all that is necessary is to have a duplicate set of knife frames. The knives of the cutter are in sets of two, placed end to end in each frame. They have a smooth edge and therefore give a smooth chip. The chips were evenly cut and of symmetrical shape, as

was shown by the samples I sent you at the time these experiments were made. There would be no difficulty whatever in filling these machines with grooved knives and thus securing a grooved chip like that I have already described. The rate of revolution of the disk is one hundred and twenty per minute.

The base of the machine is to be placed in a pit, so that the disk may come even with the surface of the ground. The hoppers will then be of a convenient height to receive the cane directly from the hands of the workmen. This disposition might also be secured by placing the driving machinery above the disk. This arrangement, however, would require the erection of a costly support for the machinery, which is avoided by the plan shown in the figure. With such a cutter the cane may be delivered by trams or from carts on all sides and the labor of placing the cane in the hoppers will be only a little greater than putting it on an ordinary carrier. I was at first inclined to hold the opinion that any cutter which proposed to do away with a cane carrier would not be suitable to this country, where labor is comparatively dear. But since the inspection of this cutter I do not consider that an important objection. The arrangement of the cutter with reference to its connection with the battery is shown in Fig. 9.

THE CUTTERS OF THE SUDENBURG COMPANY.

The cutter used in Java, in the experiments of which a résumé is given further on, was made by the Sudenburger Maschinenfabrik, of Madgeburg. I have not a detailed drawing of this cutter, but from the description of it I learned that it is constructed on the same general principles as the one made at Sangerhausen. It has a multiple feed and the disk is horizontal. The knives are ungrooved, and hence the surfaces of the chips are flat. I had an interview with M. Lucassen, of the Hague, one of the chief promoters of the Java experiments, who assured me that the cutter gave entire satisfaction and would easily furnish 200 tons of chips per day. The knives were changed only once in four or five days, but it must be remembered that the apparatus was not kept constantly at work. It would be found profitable, perhaps, to keep the knives sharper by changing them more frequently. The cane was delivered to the knives by gravity alone through a feed box, inclined at an angle of 40 degrees. There seems to have been no trouble in securing a good, even feed in this way.

The fear that the hard skin of tropical cane would prove a serious obstacle to its successful slicing has not been realized in Java. The power required to drive the apparatus was not great, and, as has been said, the knives could be used a long time without regrinding.

So successful were the results of the Java machine that the Fives-Lille Company has adopted it for the plants which they will construct hereafter.

THE FIVES-LILLE CUTTERS USED IN SPAIN.

A view of these cutters is seen in Fig. 14 A. The disks are vertical, but the canes are delivered to the perimeter of the disk at right angles to its axis. The knives are fixed in the V-shaped edge of the disk, each set consisting of two knives forming the sides of the V. The chips pass through the pocket, which receives the knives, and fall out of the open ends of the disk into the pit B. The chief fault of these cutters is the one which characterized the Ottawa machines. They can only be fed at one point, and thus have to be made very large to secure the required cutting capacity. The knives were ungrooved and the chips flat. The cutters of the factory at Almeria are precisely like those of Torre del Mar, as seen in the figure above mentioned.

CUTTERS AT BRACALAY, BRAZIL.

These cutters, three in number, were made in Austria, and were intended to have a capacity of 100 tons per day each. In practice, however, it was found that they fell short of giving this maximum result. The construction of the apparatus is very simple, and is shown in Fig. 10 A, B, C. The steel disk A is provided with three pockets, each carrying two knives. The disposition of the knife is shown in C. The rate of revolution of the disk is 80 to 100 turns per minute. A higher velocity was not practicable on account of the low resistance of the disk.

According to the experiments made the diffusion took place more rapidly as the chips were thinner. With cossettes of 1.5 millimeters thickness a cell could be emptied every two and one-half to three minutes. The action of diffusion is more prolonged if the thickness of the cossettes is increased to 2 to 2.5 millimeters.

The thickness of the cossettes is determined by the projection of the knife C at *a*. The canes are pressed against the knives through the feed box *b* by the force of gravity alone. The plane of this box makes an angle of 30 degrees with the vertical. The knives had to be changed every two hours in order to keep them sharp. This experience, so strongly in contrast with that of Java, leads to the conclusion that the steel of which the knives were made was of poor quality. In order that the feed box should not become choked it was necessary to place in it not more than a dozen canes at a time, although it was designed to carry many more. The cutters were placed above the diffusers, the canes being loaded in wagons and carried to the cutters by an elevator. The manager of the factory, as was to be expected, has found this disposition very defective, and in another season the cutter will be placed on the level of the ground and the chips carried to the diffusers by elevators. The diffusion is made in a battery of twelve cells placed in a single line. The diffusers are entirely cylindrical and the discharge gate has the same area as the cell, thus corresponding to conditions the most

important in diffusers for cane. The method of filling the cells in the Brazil factory is much like the one employed in the experiments at Ottawa.

In concluding this study of cutters I desire to insist on the importance of having a grooved chip. With ten cells at Ottawa, working with grooved chips, a degree of exhaustion was obtained higher than in any other of the experiments which I have been permitted to study. The adaptation of the knife to give a grooved chip is so easy a matter that it can be accomplished with any of the cutters which have been invented. Further, it appears that the horizontal has many decided advantages over the vertical disk, chief of which is the possibility of adapting a multiple feed, a feature of cane-cutters which was early pointed out by a citizen of this country, Mr. R. Sieg, of New Orleans.

DIFFUSION AT ALMERIA, SPAIN.

On December 16, 1885, I received from you the following instructions:

WASHINGTON, *November* 25, 1885.

SIR: I inclose you a letter which I have just received from Mr. Colcock, the secretary of the Louisiana Sugar Exchange, for your information and guidance. I have written Mr. Colcock to say that I shall comply with the request and direct you accordingly, although it will embarrass our fund somewhat. Everything in your division and in the Department is moving smoothly, and everybody seems to recognize the importance of your present trip to the sugar industry.

NORMAN J. COLMAN,
Commissioner.

Dr. H. W. WILEY,
Paris, France.

Following is the inclosed letter from Mr. Colcock:

SIR: Hon. Duncan F. Kenner, president Louisiana Sugar Planters' Association, and a director in this exchange, instructs me to write you as follows: The sugar planters feel a deep interest in the mission of Professor Wiley to Europe, but regard the information to be gained by visiting the beet region as inferior to that which may be obtained by an examination of the diffusion of sugar-cane as conducted at Almeria and Malaga, in the southeastern part of the Spanish peninsula. Machinery put up there by the Fives-Lille Company (64 Rue Caumartin, Paris, France) last year is reported to have worked with complete success, both upon cane and upon bagasse. It is probable that the Fives-Lille Company will put Professor Wiley in the way of acquiring all the information we can desire, and by a personal inspection of their plants he will be able to determine the value of both diffusion and carbonatation. As a visit to Almeria would consume but a few days of his time, Mr. Kenner asks the Department to instruct Professor Wiley to make this visit, and to prepare a special report to be immediately promulgated by the Department. Our industry needs all the encouragment it can get, and is capable of more development than any other coming within the range of the efforts of your Department. Feeling that we have no surer friend than yourself, who have devoted so much of your time and talent to the question of "home supply" of sugar, and already accomplished so much towards its attainment, Mr. Kenner has no doubt that you will give his request your careful consideration, and hopes you will accept his suggestions.

D. D. COLCOCK,
New Orleans, La., November 23, 1885.

Hon. NORMAN J. COLMAN,
Commissioner of Agriculture.

At the time of the receipt of these instructions I had made engagements to be present at certain experiments in Germany already mentioned. Realizing, however, the importance of securing early information on the subject, I sent you a preliminary report, which I was able to collate from information received of the Fives-Lille Company, constructors of the apparatus, from Signor Cosme Regas y Pompido, one of the stockholders, and from M. Pellet, the chemist who made the analyses of the campaign of 1885. Following is a summary of the chief points of the preliminary report:

INSTALLATION.

"The factory at Almeria was constructed by the Fives-Lille Company, head office 64 Rue Caumartin, Paris, works at Lille. It consists of a diffusion battery of fourteen cells, arranged in circular form. Each cell is cylindrical in shape, and the door for withdrawing the exhausted chips occupies the whole of the base of the cell. The joint is made by hydraulic pressure by means of a rubber tube imbedded in the walls of the cell and protruding far enough to press upon the flat surface of the door. The pressure in this tube is supplied by connecting it with a water service one or two meters higher than that which serves the diffusers. I made a careful study of the workings of this joint at Abbeville, north of France, and its efficiency and simplicity leave nothing to be desired.

CAPACITY OF CELLS.

"Each of the cells has a capacity of 25 hectoliters, and the vertical is twice as great as the horizontal diameter. The weight of cane chips required to fill each cell is 1,215 kilograms. The quantity of diffusion juice drawn off at each charge was 13.5 hectoliters or 111 liters for each 100 kilograms of cane diffused. It was easily possible to make two hundred diffusions a day, but owing to the lack of capacity in the cane-cutters used and the lack of skill among the workmen, not more than half this number was made.

CANE-CUTTERS.

"The cane-cutter was composed of a vertical disk, 5 feet in diameter, furnished with eight knives. The cutter did not give entire satisfaction and it is to be replaced with a new one made by the Sudenburg Manufacturing Company. This new cutter, plans of which I have seen, consists of a horizontal disk containing eight or ten knives, and is fed by hand from above through hoppers placed at a very acute angle.

"Mr. D. Lucassen, of La Hague, Holland, who has used this cutter in experiments in Java, told me that it worked well and gave him entire satisfaction. Much to my surprise he informed me that he only found it necessary to change the knives once in two or three days, and that the machine had been run five days without resharpening the knives,

doing good work all the time. The Fives–Lille Company have purchased the right to make this cutter, and are building the one to be used at Almeria.

CLARIFICATION.

"The apparatus for clarification consists of a complete outfit for double carbonatation, including lime-kiln, gas-pump, carbonatation-pans, filter presses, &c. The Java factory before spoken of has also a complete outfit for double carbonatation.

EVAPORATORS.

"The juice issuing from the filter press passes to a double effect vacuum pan, whence, having reached a density of 20° B., it is boiled to grain in a vacuum strike pan. The arrangement and capacity of this apparatus demand no further discussion at this time.

WORK DONE LAST SUMMER.

"Fortunately I met here Signor Cosme Regas y Pompido, one of the principal shareholders and a managing director of the works, and M. Barron, the superintendent of erection and of the work of the apparatus during its first season. To these gentlemen and to the courteous officials of the Fives-Lille Company—among whom I must name MM. Avisse and Cohue—I am indebted for the very valuable information which is here summarized.

"Owing to delay in completing the works the season was not opened until June, although the proper time to begin is the first of March. As a consequence, part of the cane was injured by a second growth and part of it was very dry. The season lasted from the middle of June until the middle of July.

"*Cane diffused.*—Total weight of cane worked was 1,512,216 kilograms.

"*Masse cuite obtained.*—The weight of *masse cuite* obtained from the cane worked from the 21st of June to 10th of July, viz: 1,286,170 kilograms, was 10,882 hectoliters, specific gravity 1.44 — or 155,808 kilograms — or nearly 11 per cent. of the cane worked.

SYNOPSIS OF THE CHEMICAL CONTROL.

JUICE OF THE CANE.

"The mean of nineteen analyses of juice obtained by pressure is as follows:

Specific gravity		1,061.5
Sucrose	per cent	13.83
Glucose	do	1.05
Glucose per 100 of sucrose		7.60

DIFFUSION JUICE.

"The means of seventeen analyses are as follows:

Specific gravity		1,040.5
Sucrose	per cent	38.80
Glucose	do	.669
Glucose per 100 of sucrose		7.60

JUICE FROM FIRST CARBONATATION.

"The means of fifteen analyses are as follows:

Specific gravity		1,036.1
Sucrose	per cent	7.83
Glucose	do	.465
Glucose per 100 of sucrose		5.93

JUICE FROM SECOND CARBONATATION.

"The means of seventeen analyses are as follows:

Specific gravity		1,035.7
Sucrose	per cent	7.83
Glucose	do	.384
Glucose per 100 of sucrose		5.18

MASSE CUITE.

"The results of one analysis are as follows:

Water	per cent	17.50
Sucrose	do	72.50
Glucose	do	.80
Ash	do	6.06
Not sugar	do	2.84

FILTER PRESS CAKE (ONE ANALYSIS).

"Water	per cent	37.00
Sucrose	do	4.00

Exhausted chips, mean of ten analyses, sucrose 0.188 per cent.

OBSERVATIONS ON THE ANALYSES.

"The degree of extraction at Almeria is strikingly like the results obtained at Ottawa, and described in Bulletin No. 6.

"The total sugar and soluble matter are the same or nearly the same in both instances. Also the specific gravity of the diffusion juice and the percentages of *masse cuite* obtained are very much alike. In the effect of carbonatation on the glucose present, however, there is a marked contrast. At Almeria by the process of double carbonatation one-third of the glucose was destroyed, the quantity per hundred of sucrose falling from 7.60 to 5.18.

"At Ottawa with a juice in which the proportion of glucose was three times as great, the rate of loss was less. Indeed if we should rely on the analyses of *masse cuite* given above it would be easy to conclude that the process of double carbonatation destroyed, practically, all the glucose. An inquiry as to the manner of conducting the carbonatations at Almeria led to an explanation of the above loss in glucose. The juice as it left the diffuser had a temperature of about 50°, twice that of our experiments at Ottawa. It was immediately sent to the carbonatation pan, and by the time the process was finished it had reached a temperature of 60°. Thus the first carbonatation was made at a temperature much above that of the Ottawa experiment. Passing through

the filter press the temperature was somewhat reduced, but the whole of the second carbonatation was made at a temperature above that of the first. I am only surprised that the loss of glucose was not greater, but this is accounted for by the small percentage of lime used, viz: 1 per cent. for the first carbonatation and .25 per cent. for the second.

TEMPERATURE.

"The temperature of the liquid in the cells was kept at 80° to 90°. This high temperature avoided all danger of fermentation, and doubtless helped to a more perfect extraction of the sugar. Neither did the high temperature have any bad effect on the color of the juice, it being always a light amber.

EXHAUSTED CHIPS.

"The only loss of sugar in the process of diffusion is in the exhausted chips, since compressed air is used to drive the last charge of water out of the cell which is next to be emptied. This loss, as is seen, is practically that of both chips and waste water in the Ottawa experiment."

DIFFUSION IN SPAIN.

On the 2d of January this year, having returned to Paris from Germany, I started on my journey to Spain, accompanied by M. Cohue, of the Fives-Lille Company. At Madrid we were joined by M. Borghi, the engineer who assisted in erecting the works. Proceeding by rail to Cartagena I took passage in a coast steamer for Almeria, arriving there on the morning of January 8. The factory at Almeria, I believe, is the first one that has been built for cane in which the processes of diffusion and double carbonatation were originally introduced. The factory is complete in every respect and entirely new, having been operated only one season, viz: 1885. Owing to delay in erecting the machinery the campaign did not open until June, 1885, although in Spain the usual season for beginning the manufacture is in March. The general plan of the factory at Almeria is shown in Fig. 11. As shown in the plan the diffusion battery has sixteen cells; only fourteen, however, have been erected, but the apparatus is so arranged that the other two can be added at pleasure. For this season the company will continue to work with the present number. The cutters, system of Geay and Janin, have already been described. They are fed by hand and gravity is relied upon to force the canes against the knives, the feed hoppers being inclined to the vertical at an angle of 45 degrees. The cane is brought to the hoppers by hand, no cane-carrier being used.

The disposition of the elevator of the fresh chips and the method of delivering them to the cells are shown in Fig. 12. The same figure also shows two cells at opposite points of the battery, one closed and the other open. The belt of the elevator is made of ropes placed side by side.

To these are fastened buckets. The chips fall into these buckets and are carried up on the upper side of the apparatus. This is a much better arrangement than is secured by carrying them in a trough by scrapers fastened to the belt and moving in the opposite direction from that described. The angle of the elevator is 40 degrees. The trough into which the chips fall has an angle of 45 degrees, but may be inclined a little more or less to suit the requirement of the building. In all cases, however, it must be steep enough to allow the chips to fall freely into the cells. The expansion of this trough at the top, where the chips are received from the elevator, is 1 meter in diameter.

The chips from the cells fall into a pit, whence they are taken by a bucket elevator and dropped into cars, which take them out, on a roadway built on trestle work, and drop them. Attempts were made to dry the chips by passing them through an ordinary press, such as used for beet pulp. This press, however, left nearly 80 per cent. water in the chips, and in this condition they are not fit for fuel. Before the chips become valuable as fuel their percentage content of water must be reduced to about 50.00. The chips, after lying in heaps until partially rotten, are used as manure. The diffusion juices are received in a measuring tank as indicated in Fig. 11, whence they pass into a larger tank, and thence, through a juice pump, to the carbonating pans.

The pans for the first carbonatation are three in number and have each a capacity of 2,500 liters. They are furnished with copper steam coils for heating the juice, and are provided with tight covers and a flue for the escape of the superfluous gases. The cream of lime is added in the pans; perhaps not the best plan, but a convenient one. The amount is varied according to the quality of the juice, but the mean is about 1.5 per cent. of pure lime.

After the first carbonatation is completed the juice falls into a *monte-jus*, by which it is forced through the filter presses. From the filter presses the juice runs into the pans for the second carbonatation, two in number, and of the same size and general arrangement as for the first process. The amount of lime added for second carbonatation is much less than for the first, varying from .25 to .5 per cent. From the second carbonatation the juice passes to a second *monte-jus*, whence it is sent again through the filter presses. The filtered juice is received in a tank and elevated by a pump to the bone-black filters. It will be at once seen that by the arrangement of the machinery at Almeria the juice has to be frequently handled. In the last processes mentioned it would have been a very easy matter to have placed the filter presses for the juice of second carbonatation a little higher and thus allowed it to run directly into the bone-black filters. This would save one handling of the juice by the pump. From the bone filters the juice passes at once to the triple effect, and its subsequent manipulation is entirely similar to that employed in the best beet and cane sugar factories.

In the Almeria plant all tubes through which the juice flows, including all the connections of the battery, are of copper.

The lime-kiln is of the usual construction, being provided with three lateral furnaces, which are not used, however, except when the furnace is first started. The coke is mixed with the limestone and fed in at the top of the kiln. The coal used is almost all brought from England and the coke is furnished by the gas factory in the town. The sugar factory at Almeria is built in a locality where sugar-cane has not been grown before. The peasants have not yet undertaken the cultivation of the cane to sell to the company, which last season and this cultivated its own cane. As soon as the method of cultivation is understood the cane will be grown for the company by the small farmers. The cane is grown only on alluvial soil near the sea and where irrigation can be practiced. The cane fields are irrigated five or six times a year.

The cost of producing the cane is about $8 per 1,000 kilograms. I visited some of the company's cane fields and noticed the characteristics of the cane. At the time of the visit the cane had obtained its full growth. The stalks are short, the mean length as they are brought to the mill probably .75 meter. The top blades were of a yellow tint, and when this color extends to all the blades the cane is said to be ripe. This occurs at the end of March or beginning of April. The average life of the cane is five years, though in many instances fields have been allowed to stand ten or fifteen years. There is no danger of the stubble ever being killed by frost. Light frosts often occur in the late winter or early spring, but are never severe enough to do any damage to the roots. The latitude of Almeria is 37° north. When not working the indigenous crop the factory refines Cuban sugar. This sugar is delivered at the port of Almeria directly from Cuba. Spanish factories do not pay a tax on quantity of cane worked or sugar made, but a certain sum is paid each year; just how much I was not able to discover. But the tax is certainly light compared with that of France or Germany on beets. Foreign refined sugar entering Spain pays a tax of 72 pesetas* per 110 kilograms. Raw Cuba and other colonial sugars pay 17.50 pesetas per 100 kilograms. Raw sugars from other countries pay a much higher duty. In this manner the Spanish Government favors its own colonies. The wholesale price of refined sugar in Spain is from 100 to 110 pesetas per 100 kilograms. The retail price is of course considerably greater, and when this high price of sugar is considered in connection with the general poverty of the people the low consumption of sugar per head is not a matter of wonder. The buildings of the Almeria company are all new, substantial, and of stone. The company also builds the houses occupied by its employés. Last fall, when the cholera destroyed one-sixth of the population of Almeria, there was not a fatal case among the employés of the factory. It would be unwise to suppose from this that a sugar factory is a protection against cholera. The immunity of

* Peseta = 19¾ cents.

the employés doubtless arose from the fact that they had access to an untainted supply of water and lived in new and clean houses.

There is no regret on the part of the company at Almeria at having chosen to erect a diffusion plant instead of a mill. This is probably the first cane-sugar factory of the world that was planned and built for the use of diffusion and carbonatation. Its success therefore has a peculiar and particular interest. While Spain in many respects is behind the rest of the world in modern progress we must confess, and perhaps should do so with a certain degree of humiliation, that in the matter of the manufacture of sugar from cane it has gone far ahead of the United States, not in the quantity made, but in the character and kind of machinery employed. There are in all about twenty-five cane-sugar factories in Spain. I am indebted to the Fives Lille Company and their chemist, M. Pellet, for the following additional items of information concerning the campaign of last year:

The first experiments were made at Almeria, Spain, during the months of June and July, 1885. As can be seen by the following table of analyses these canes were not of a superior quality. We take at hazard a few of the analyses:

Date.	Specific gravity.	Sugar.	Glucose.	Glucose per 100 sucrose.
		Per cent.	*Per cent.*	
June 24	1, 051. 4	10. 39	1. 718	16. 64
June 30	1, 059. 4	13. 93	0. 982	7. 05
July 4	1, 058. 5	13. 05	1. 036	7. 96
July 8	1, 067. 9	16. 13	0. 880	5. 46
July 12	1, 072. 2	17. 28	0. 693	4. 01

From a series of analyses carried on during the entire period of the work it is calculated that the average juice had—

Specific gravity		1, 061. 5
Sugar	per cent	13. 83
Glucose	do	1. 053
Glucose to 100 of sugar		7. 68

From this result the richness of the cane can be deduced on the supposition that it contained 88 per cent. juice:

By the formula $\frac{13.83 \times 88}{1.0615 \times 100} = 11^{k}.45$ of sugar per 100 kilograms of cane.

But the canes being in part very dry, according to the volume of juice extracted per 100 kilograms of cane, the mean richness was about 10 per cent. The juices of diffusion likewise presented some considerable variations according to the quality of the cane. For example, the diffusion juice had on—

	June 24.	July 12.
Specific gravity	1, 039. 9	1, 043. 2
Sugar, per cent	8. 82	10. 09
Glucose, do	0. 887	0. 503
Glucose per 100 sugar	10. 06	4. 98

As for the normal juice, so also the mean quantity of the juice of diffusion and the proportion of glucose were calculated, and there was obtained:

Specific gravity		1,040.5
Sugar	per cent	8.8
Glucose	do	0.669
Glucose per 100 of sugar		7.60

In calculating the coefficients of purity, it was found that the juice of diffusion was a little less pure than the juice of the mill; the difference is due solely to the nature of the water employed for diffusion, which contained some considerable proportions of saline matters in solution.

The fact of principal interest brought out by these two mean analyses is that diffusion does not increase the proportion of glucose per 100 of sucrose.

It will be seen further along, in the experiments made at Java, that diffusion conducted with water of good quantity furnished raw juices purer than the juices from the mills.

LOSS OF SUGAR IN EXHAUSTED CHIPS.

At Almeria, from a large number of experiments the percentage of sugar in the exhausted chips was nearly .19, using fourteen diffusers. At Java, on the contrary, the quantity was .85 per cent., in consequence of the small number of cells, only ten being used.

It is, then, certain that, with a sufficient number of diffusers, there would be left in the exhausted chips only from .10 to .20 per cent. of sugar where 110 to 112 liters of juice are withdrawn for each 100 kilograms of cane worked.

CARBONATATED JUICE.

At Almeria the juices of the first carbonatation presented the mean constituents below:

Specific gravity		1,036
Sugar	per cent	7.83
Glucose	do	0.465
Glucose per 100 sugar		5.92

It is therefore a fact well established that by carbonatation the proportion of glucose per 100 of sucrose is diminished.

From 7.60 per cent. in the juice of diffusion it has fallen to 5.93 per cent., a difference of 1.67 per cent.

A like result was obtained at Java. The juice of diffusion had 5.55 of glucose per 100 of sucrose, mean of more than one hundred analyses, and the juice of carbonatation contained only about 2 parts per 100. The same fact was observed with the concentrated sirups, which contained only 1.9 parts of glucose per 100 of sucrose.

The *masses cuites* at Almeria had an inferior quality in consequence, as has been said, of the poor quality of the cane.

They contained, of—

	Per cent.
Water	15.0 to 17.3
Sugar	72.5 77.0
Ash	6.0 5.5
Glucose	0.8 1.0

Thus the proportion of ash was more than 8 per 100 of sugar, although at Java it was only 4 to the 100.

This is one reason why at Almeria the yield has been relatively small, but it is necessary to add that with mills and canes of the same quality nothing better could have been said.

The yield of sugar altogether was 6 per cent., and of molasses the same.

But it has been shown that the canes did not contain more than 9.5 to 10 per cent. of their weight in sugar. If from this number are deducted the total losses in extraction and in manufacturing, that is, .65 per cent., there would be left only 9 per cent. in the state of sugar and molasses. This is the quantity which was obtained.

From all the experiments which have been made at Almeria the following results appear:

Diffusion applied to cane permits the extraction of almost the whole of the content of sugar.

The operation is carried on without difficulty on chips furnished by a cutter thoroughly practical.

The degree of extraction shows only .10 to .20 per cent. of sugar in the chips when a sufficient number of cells is employed.

The specific gravity of the diffusion juices varies, and can reach 78 to 80 per cent. of that of the juice of the cane.

The proportion of glucose to sucrose is the same in diffusion as in cane juices.

The purity of the diffusion juice is slightly inferior to that of the mill.

The juice of diffusion can be purified either by carbonatation or by ordinary defecation. The *masses cuites* obtained from diffusion juices are exactly of the same composition as those obtained in the same way from mill juices.

The same fact is observed in beet-sugar factories. If the juices in the raw state differ after a proper and well-conducted purification, the juice of diffusion and of the press give a *masse cuite* sensibly of the same purity.

But it is certain that, on account of the nature of the impurities of the raw juices from the diffusion of cane, this latter can be preserved much better than that obtained by passing the canes through a mill. The matters easily alterable remain in the chips heated to 85° or to 90° C.

Finally, it may be said that diffusion will allow the extraction of the

maximum quantity of sugar from the cane. The difference between the amount extracted by diffusion and by the mill will, of course, vary according to the excellence of the mill. Nevertheless we may take as a mean the following figures:

Juice extracted to per cent. of cane	67.0
Percentage of sugar in juice	16.5
Percentage of juice in cane	89.0

The loss in the bagasse would be 89—67=22 per cent. of juice × 16.5 = 3.63 of sugar lost per 100 of cane.

By diffusion would be lost only 0.2; thus the sugar saved would be 3.43 per cent. Of the 3.43 per cent. at least 70 per cent. could be obtained as dry sugar, or 2.3 per cent., and the rest, 1.13 per cent., would go to increase the proportion of molasses.

I will add a word to these interesting observations of M. Pellet. The fact that the juice of diffusion is a little less pure than that from the mill I had already pointed out in the Ottawa report. M. Pellet explains this result at Almeria by attributing it to the impurity of the water used. I think it is more probably due to the solvent action of the water on the gums and other bodies which would remain in the bagasse of the mill, but pass into the waters of diffusion. As I have said in a previous report, the great advantage of diffusion applied to cane is not in securing a purer juice, but in getting a larger yield of sugar. But at any rate, the greater degree of impurity, should it be shown to exist by further experiment, is so small in the diffusion juices that it ceases to be an objection to the application of the process.

It will not be surprising to find that in the results of the analyses of the carbonatated juice made at Almeria and in Java, as will appear further along, the proportion of glucose per 100 of sucrose is diminished. Both the first and second carbonatation were made at a high temperature, not much below the boiling point. We would suspect that at such a temperature the lime would rapidly attack the glucose and destroy it. The matter of surprise to me is that with a double carbonatation made at so high a temperature the proportion of glucose was not diminished to a much greater extent then the analyses indicate. One of the chief objections to the introduction of carbonatation in cane-sugar manufacture has been that it would destroy the yield of molasses. This led to the experiments in cold carbonatation which, first tried in the laboratory with approval, afterwards succeeded so well at Ottawa on a large scale. Not only was the glucose not destroyed but, what was equally gratifying, the resulting molasses was not even darkened.

In recommending a single cold carbonatation I have had in view, not the sugar, but the molasses product. There is no doubt but that a slightly greater yield of dry sugar can be obtained by practicing double carbonatation. In Java and other tropical countries, where the sugar production is the chief, and I may say the only object to be obtained, double hot carbonatation, is certainly to be preferred. But in the

United States, where the yield of molasses is an important part of the product, I still feel quite sure that the best results will be obtained by practicing single cold carbonatation, followed by saturation with sulphurous acid. Cane juices, whether sorghum or sugar cane, are much more easily purified than those of beets. Hence the desirability of a second carbonatation is not so great where cane is worked. In my opinion, the sulphur saturation will be found to be of much greater advantage than the second carbonatation.

APPLICATION OF DIFFUSION TO THE EXTRACTION OF SUGAR FROM BAGASSE, AT TORRE DEL MAR, SPAIN.

The sugar factory at Torre del Mar can be reached only by a private conveyance from Malaga. The distance is nearly 40 kilometers. The road is generally good and runs along the shore of the Mediterranean Sea. With three horses to a small carriage, the distance was covered in three and a half hours. The road in many places is built into the sides of the barren hills that touch the shore, while at others it crosses fertile and irrigated valleys, covered with orchards of oranges and fields of sugar-cane. The factory has been in operation many years, and purchases the cane from the farmers, paying a mean price of about $8 per 1,000 kilograms.

The factory is the property of Signor Larios, who, being a member of the Spanish Cortes, was, at the time of my visit, in Madrid. While passing through the capital, an attempt was made to see Signor Larios in person, but he was not found at home. The factory has connected with it both a refinery for raw sugars and a distillery, and it is impossible to gain entrance to it without authority from the proprietor. I had left a request in Madrid that a written permission to inspect the factory be sent to me at Malaga, but on arriving at this place nothing was found. After waiting two days, hoping for the arrival of a letter, a telegram was sent to Madrid urgently asking for the desired permission as a favor to the United States Department of Agriculture. On the following morning I was gratified by the receipt of a telegram from Signor Larios according the favor desired.

Before I had seen the arrangement of the apparatus at Torre del Mar, and learned from the resident director of the gratifying success which had been secured, I was exceedingly skeptical in respect of the advantage of attempting the diffusion of bagasse. This doubt was largely removed by my visit, and the reasons therefor will appear in the following detailed account of the factory and its workings.

THE FACTORY AT TORRE DEL MAR.

At this establishment, in 1876, a number of large, open tanks were erected, in which the bagasse, after two or three pressures, was thrown and subjected to maceration. The results of the treatment were suffi-

ciently encouraging to have the proprietors erect a diffusion apparatus, which was so arranged as to be used either with cane chips direct or with the bagasse from the mills. This apparatus was built by the Fives-Lille Company, and a full description of it, with illustration, is appended.

This apparatus was erected in 1883, and is therefore the first diffusion battery to be used with sugar-cane in Europe.

During the season of 1884 half the crop was worked by diffusing the cane chips directly and half by first subjecting the canes to double or triple pressure, and afterwards diffusing the bagasse.

The general results of this trial led to the abandonment of the direct diffusion of the chips, and, therefore, during the campaign of 1885, only the bagasse was diffused. The director of the works, Signor Alizandro Delorme, gave me a very full exposition of the reasons which led him to adopt this course. The capacity of the cells, as will be seen by the appended description of the machinery, was entirely too small to allow of rapid working, and with a crop of 10,000 tons this is a matter of considerable importance. Further than this, he considered that the cells were too few in number. He agrees with the engineers of the Fives-Lille Company and the director of the Almeria factory that the best results in the direct diffusion of cane will be given by a battery of fourteen to sixteen cells. The amount of sugar left in the cane chips was 2.4 kilograms for each 1,000 kilograms of chips. This result scarcely justifies the belief in the necessity for a larger number of cells, since a loss of .25 per cent. of sugar is not greatly in excess of the best results that can be expected of diffusion.

But the chief reason which led to the abandonment of the direct diffusion of the chips was the absence of apparatus for carbonatation. Signor Delorme found that the defecation of the juices of diffusion by the ordinary process gave less satisfactory results than were obtained with the mill juices. The diffusion juices did not contain a sufficient percentage of albuminous matters to produce a good defecation. This is entirely in harmony with my own experience, and is the result which led me long ago to declare that diffusion and carbonatation are the Chang and Eng of a rational extraction of sugar from cane. Signor Delorme further said that if he were erecting a new factory he would most certainly use diffusion and carbonatation, and would abandon the use of a mill. But with two large mills on hand and a diffusion apparatus which is too small to use with cane chips he will continue the joint use of the mill and battery.

The two mills of the Torre del Mar factory are not arranged *tandem*, as is generally the case, but are entirely distinct in their engines and operations. Neither of them is furnished with a cane or bagasse carrier, in each case the handling being done by hand. This arrangement is of course possible in a country where the most abundant product, and one for which there is the poorest market, is human labor. With

each mill a certain quantity of cane is ground, and the bagasse carried back and placed in heaps. After the crushing is completed the bagasse is put through the same mill, and afterwards this process is sometimes repeated. By the three crushings a mean of 70 per cent. of extraction is secured. By this time the bagasse is pretty well broken up. It is then carried by hand, without any further cutting, and placed in the diffusers. The diffusion battery is placed opposite the large mill, which has a crushing capacity of 170 tons in twenty-four hours. The capacity of the battery is just sufficient to take the bagasse from the mill. If double or triple pressure is employed, then it can take the product of both mills.

During the last campaign, 1885, 9,924 tons (1,000 kilograms each) of cane were worked. From the mills 6,116.9 cubic meters of juice were obtained, and from the bagasse 3,116.5 cubic meters. The total volume of juice obtained was, therefore, 9,233.4 cubic meters, or, in hectoliters, 92,334. The average density of the mixed juices was 1,047, and hence the total weight of juice obtained was 9,660 tons (1,000 kilograms). The ratio of cane to juice was, therefore, 1 to .97.

It is thus seen that the juice was of considerably greater density than can be expected of the juices obtained by the direct diffusion of the chips.

I was kindly allowed to copy some of the analyses of the mill and diffusion juices from the records of the laboratory.

I selected dates extending over nearly the whole of the campaign, and which would give a fair idea of the general results obtained:

Date.	Mill juice.				Bagasse diffusion juice.			
	Sucrose per liter.	Glucose per liter.	Ratio sucrose to glucose.*	Specific gravity at 16°.	Sucrose per liter.	Glucose per liter.	Ratio sucrose to glucose.*	Specific gravity at 16°.
1885.	*Grams.*	*Grams.*			*Grams.*	*Grams.*		
March 27	87.75	15.23	17.36	1,049	41.22	7.42	18.00	1,022
April 14	102.93	12.86	12.49	1,055	53.71	5.26	9.79	1,025
April 16	118.17	10.33	8.74	1,057	54.12	4.38	8.09	1,024
April 17	115.03	13.15	11.43	1,057	55.36	4.74	8.56	1,024
April 21	119.43	13.46	11.27	1,058	55.11	6.18	11.16	1,024
May 3	116.02	11.81	10.18	1,058	55.05	4.67	8.42	1,025
May 31	147.55	7.82	5.29	1,063	61.05	4.38	7.17	1,025
Means	115.13	12.09	10.95	1,058	53.79	5.29	10.17	1,024

* Grams glucose × 100 ÷ by grams sucrose.

As is shown in the above analyses the proportion of glucose in the diffusion juice of the bagasse was less than in that of the mills, a fact which is rather surprising when it is remembered that the diffusion of bagasse is really a maceration and not a diffusion in the proper sense of the term. The results of the two seasons' work at Torre del Mar are convincing of the fact that the juice obtained from the bagasse is fully equal in purity to that obtained from the mills. The mixed juices, although considerably more dilute than the mill juice, worked well in

the defecating tanks, but there is no doubt whatever that they would do even better with carbonatation. The important point here to be considered, however, is, that with a mill and a battery it is quite possible to work very well without a carbonatation apparatus.

The analyses of the exhausted bagasse showed that very little sugar was left in the residue. I copied one analysis, that made on the 5th of May, which gave the following results:

	Per cent.
Water	87.22
Sucrose	.249
Cellulose and residue	12.53

From this it appears that the loss of sugar is about the same as was experienced in the direct diffusion of cane. It appears, also, from the amount of water which the bagasse absorbs, that the weight of it as it comes from the diffusion is about that of the original cane. The percentage of loss for the bagasse, viz: .249, would indicate that not more than .35 per cent. of the sugar originally in the cane has escaped extraction.

My visit to Torre del Mar has caused me to modify somewhat the views I expressed in my preliminary report to you, written in Paris on December 15, 1885, in which I strongly discouraged the idea of erecting a battery for the purpose of extracting the sugar from the bagasse. At that time I supposed it would be necessary to erect in connection with such a battery a complete carbonatation plant. I am now convinced that, while this is advisable, it is not necessary, and that in view of the fact that such an installation would involve the purchase of a small battery only, it might be recommended for trial by the Louisiana planters.

I would certainly, however, advise a different arrangement from that which has been adopted at Torre del Mar.

The bagasse carrier from the mill should be connected with a good ensilage cutter, as is done in the apparatus erected two years ago at Rio Grande, N. J. The finely chopped bagasse can then be elevated and handled exactly as cane chips would be in similar circumstances. The passing of the bagasse through an ensilage cutter will not only make its subsequent handling more convenient, but will also allow it to lie closer together in the diffusion cells, which is a matter of great importance. In the apparatus at Torre del Mar, the weight of bagasse which was placed in each diffuser was about 250 kilograms, and the volume of juice drawn off from each one 4 hectoliters.

The cells are so arranged that the exhausted bagasse, when the lower door is opened, falls directly into carts, which transfer it to the manure pits. These pits are 1 meter deep, and the bagasse is piled up to a depth of 2 meters above the surface. The top is then covered with dirt, and the refuse of the distillery (connected with the factory) is poured into it. The dirt prevents its too rapid absorption, and this treatment is continued for a year. By this time the mass is well decomposed and saturated with valuable manurial materials. It is now re-

moved and placed in large heaps and sold to the farmers. It is a valuable manure, both chemically and mechanically.

The treatment of the residue (exhausted chips) is a matter of first importance in the problem of the application of diffusion to cane. With good mills the bagasse becomes a valuable fuel, but in the process of diffusion the exhausted chips are unfit for fuel, and to press and dry them would require almost as much power and expense as grinding the cane.

I have frequently pointed out the value of the chips as a mechanical fertilizer, operating as they would to keep the soil porous, thus allowing a free circulation of the air. At Torre del Mar, however, thanks to the presence of a distillery, the exhausted chips are made to act both as a chemical and mechanical fertilizer. In the stiff alluvium of Louisiana the chips will be found valuable, however, without the preliminary treatment. In the opinion of Signor Delorme, the bagasse, as prepared at Torre del Mar, has a value scarcely, if at all, inferior to stable manure. I was much interested in the thoroughly practical manner in which this company had solved the problem of diffusion residue. If in a country like Spain, where fuel is enormously dear, as compared with Louisiana, they have satisfactorily disposed of one of the great objections to diffusion, we ought not to despair of being able to reach a satisfactory result at home.

The company at Torre del Mar also prepares the fertilizer which appears best suited to the soil of the locality. This soil, I may say, is all alluvium, brought down from the mountains by the streams. Sugar cane is grown only in these alluvial deposits along the coast.

These soils have been carefully analyzed by the chemist of the establishment, as well as the canes entire, and the fertilizers are so compounded as to furnish the growing crop those articles of mineral and organic food most essential to its wants. The factory at Torre del Mar has every appearance of prosperity. The buildings are substantial and kept in neat order, but the one-story plan of architecture is adopted on account of the liability of the locality to earthquakes. The jagged top of the chimney of the boilers, a few meters of which were thrown down by the great earthquake of December, 1884, is an ocular proof of the wisdom of this plan.

ARRANGEMENT OF THE MACHINERY AT TORRE DEL MAR.

As already mentioned the battery was erected with the idea of using it on cane chips directly, and this course was abandoned because of the smallness of the cells and their insufficient number. The elevators which appear in the following diagrams were built to bring the cane chips from the cutters and are not used for the bagasse. This, after the second or third pressure by the mill, was taken by hand, put into baskets and elevated to the battery and placed by hand in the cells. The battery of ten cells is arranged in double line, as shown in Fig. 13. The

large outer circles show the tops of the cells and the inner smaller ones the position of the calorisators. The oval lines represent the iron tramway placed above the cells, from which are suspended the wagons which carry the cane chips from the elevator to the cells. This machinery is not used when working with bagasse. The arrangement of the apparatus for charging the cells with bagasse, therefore, is entirely deficient, and requires an amount of manual labor which would condemn it in this country.

On the other hand, the arrangement for discharging the cells is most admirable. The battery is placed high enough to permit a cart to be driven under each cell when it is ready to be discharged. The exhausted chips fall directly into this cart, and they are at once removed without the trouble of throwing them on to an elevator. Since compressed air is used for driving the last charge of water out of the cell which is next to be emptied, very little of it comes out with the bagasse. What little there is falls on a perforated floor, whence it finds its way to the reservoir. Indeed, since the bagasse is used directly from the mills, it would be difficult to handle it either with an elevator to bring it to the cells or to remove it after its discharge and carry it to a press or wagon. But, as I have said in the general description of the factory, I am convinced that good results would follow from first passing the bagasse through an ensilage cutter, by which process it would be left in a form suitable for handling mechanically. This has already been done at Rio Grande, N. J., and if diffusion of the bagasse have failed of being practicable there it is because of mechanical difficulties in the diffusers, which are those originally built for working beets, having a lateral discharge door entirely too small for the requirements of bagasse.

The plan of the general arrangement of the factory, with sections through its principal parts, is shown in Fig. 14. The cane mills are of great strength and capacity and two in number. The larger one can crush 200,000 kilograms and the smaller 125,000 kilograms in twenty-four hours. They have neither cane nor bagasse carriers. The canes are placed on a small feed table and delivered to the rolls by hand. The bagasse is gathered up and carried to the front of the mill, whence, after a sufficient quantity has been accumulated, it is again subjected to pressure. When not hurried, and generally in Spain there is no hurry, the second bagasse is subjected to a third pressure before it is carried to the diffusers.

The form of the cutting rim of the cane cutters is shown at Fig. 14, A. The canes being fed at right angles to the axis and the knives being placed with their edges evenly but slightly projecting beyond the V-shaped rim, secures the cutting of the canes obliquely. The canes also being fed at an angle of 45 degrees with the vertical and the point of incidence of the knife being in the horizontal plane passing through the axis, it follows that a double oblique section of the cane is produced. This arrangement gives a chip well shaped for diffusion. The knives are

smooth and the chips therefore have smooth surfaces, which, after coming together in the cell, produce the same effect, as far as circulation is concerned, as if they were of double or greater thickness.

The result of working with smooth chips has already had the effect of causing European sugar engineers to recommend the erection of batteries with a larger number of cells. But, curiously, they have assigned as a reason for this that cane chips diffuse with greater difficulty than the cossettes of beets, a supposition which is neither warranted by the histological structure of the cane nor by the experiments already made by the Department.

The manufacturer who would at the present day try to operate a battery with smoothly-sliced beet rondelles would doubtless also call for a battery with a great number of cells. I have every reason to believe that cane chips properly grooved will be found to lend themselves to the process of diffusion as readily if not more so than the cossettes of beets. Although in this place these remarks partake of the nature of a digression, I cannot refrain from expressing the belief that if canes were cut in convenient length and fed to an ordinary beet cutter the result would be a mass of cossettes that would pass through a battery of twelve cells and leave nothing to be desired in respect of the thoroughness of the extraction.

CONSTRUCTION OF THE CELL FOR DIFFUSION OF BAGASSE.

By far the most interesting point in connection with the details of the machinery of Torre del Mar relates to the peculiar form of the cell used, which allows an easy and prompt discharge of the exhausted bagasse. A moment's reflection will be sufficient to show that the movement of the exhausted bagasse would be more difficult than that of the chips. And this is especially so when bagasse is treated directly from the mill without passing it through a cutter. To avoid this difficulty the cells of the battery at Torre del Mar are so constructed that the area of the discharge gate is greater than that of any horizontal cross-section of the cell. In Fig. 15 are shown the details of the construction of the cell, with its pipes, valves, calorisators, &c.

The diameter of the cell at the shoulder is one meter and at the discharge gate 1.1 meters. The depth of the cell from the shoulder to the point of attachment of the cast-iron jacket is 1.4 meters, and from that point to the bottom .4 meter; the total length is therefore 1.8 meters.

The internal surface, therefore, of the cell may be regarded as the surface of a cone of very slight inclination. As a result of this shape it happens that directly on opening the discharge gate the whole of the contents of the cell at once drop out, the cell walls not being able to offer any resistance to the movement. We find in this plan of construction the last step in the gradual evolution of the diffusion cell. The first cells made, in the earliest attempts to apply diffusion to the extraction of the sugar in the cells of plants, had no discharge gate whatever.

The cells were emptied by throwing the exhausted chips out of the top of the cell with a fork or shovel. The next step consisted in the manufacture of a cell, conical in shape, but with the apex of the cone pointing downward. These were furnished with small lateral discharge gates. The next step in the evolution of the cell consisted in either making the cell in the form of a cylinder and with larger lateral openings, or in terminating the bottom of the cell by a sharply inclined cone, carrying a gate which, of course, was directly in the center of the bottom of the cell.

Next followed cells entirely cylindrical and with a discharge gate of the same area as the horizontal cross-section of the cylinder. This stage of evolution may be regarded as final for both beets and cane. In efficiency and perfection of working it leaves, in fact, nothing to be desired. But for bagasse one more step must be taken, and that has resulted in the construction of the unique cell just described. Signor Delorme was enthusiastic in his praise of the working of the battery, and there is no doubt of its efficiency and perfect adaptation to the needs of the problem for the solution of which it was designed. With such an arrangement, joined to the improvements in handling the bagasse before it enters the cells, to which I have already called attention, it appears that the process of diffusion can be profitably and easily connected with the crushing process now in use. Of course such a procedure would render it impracticable to use the bagasse issuing from the diffusers as fuel. In Fig. 16 the method of connecting two adjacent cells is shown.

DIFFUSION AND CARBONATATION IN JAVA.

In Paris I had the good fortune to meet M. Lucassen, of The Hague, one of the principal planters in Java, who, during the season of 1885, made extensive experiments in respect of the application of diffusion and carbonatation in the manufacture of sugar from cane. From M. Lucassen I received many oral items of interest concerning the work already accomplished and of the plans for future operations. He also gave me a printed report, a pamphlet of 37 pages, containing an account of the experiments and a record of the analyses made during their progress. This report is entitled "Verslag Van de Resultaten der te Djattiwangie Genomen proef met de Diffusie Gedurende Maaltijd van A°, 1885."

The report is printed in the Dutch language, and I have taken the following extracts from a French translation of it, kindly given me by M. Avisse, of Paris:

> The sugar planters of Java at their annual reunion in 1883, recognized the fact that the great loss of sugar in the bagasse even of the best mills was a serious obstacle to the prosperity of their business. At that meeting a commission was appointed, and a subscription raised to make some experiments in the direction of introducing diffusion. M. D. Lucassen was appointed a member of that commission, and being about

to set out for Europe the business of making the preliminary arrangements was gvien to him.

He wisely concluded that the first thing to be considered was the procuring of a machine which would cut cane in a thoroughly satisfactory manner. It had been reported that the cutter, system Geay (the one used at Almeria), had already been employed in some French colonies and in Spain, and had given perfect satisfaction. The committee had therefore recommended the purchase of this machine. Having arrived in Europe, M. Lucassen opened negotiations with several manufacturers of machinery, the result of which was that the Sudenburg-Madgeburg Maschinenfabrik and Eisengiesserei undertook to furnish the required apparatus. The Sudenburg company was anxious to construct a cutter of its own device since it was not willing to risk success with the French apparatus. It was then very wisely decided to construct both machines that they might be tried together. At the same time that the committee appealed to the planters in Java to make contributions to enable it to carry out the experiments, it asked that some one of them would place his plantation at its disposal. For a long time no answer was received to this request. Finally Herr Znur, one of the members of the committee offered it the use of his plantation at Djattiwangie. It was decided to accept this offer, although the distant position of Djattiwangie was a serious obstacle to a personal visit of many of those participating in the undertaking.

The cutters, with engine and connecting machinery arrived in time to be tried during the season of 1884. The experiments with these were conducted by Herr H. Von Neumer, who had come from Europe for this porpose. The German cutter after a few slight changes and additions was proved a decided success. The chips were produced of any desired thickness and were evenly cut. The quantity of them furnished by the machine was surprising: in twenty-two hours 3,200 picols* of from 3 to 4 millimeters of thickness. When the little engine which drove the cutter, of which the diameter of the cylinder was .3 meter, and length of stroke .5 meter, was compared with the ponderous engine necessary to crush an equal quantity of cane, it was evident that in respect of economy of steam the cane-cutter had a bright future.

With the French machine the results were not so favorable. It indeed furnished well-cut chips, but the insertion of the knives which, in the German machine is the work of only a few minutes, was so difficult and required so much care and time that this alone rendered its employment impracticable, much less the erection of three or four of them in the face of this inconvenience. Furthermore, the French machine did not have half the capacity of the German, being able to furnish only 1,309 picols in twenty-two hours. The German machine, with horizontal movement, furnished always chips perfectly dry, while in the French machine, with vertical movement, the chips were compressed against the conical sides of the cutter in such a way as to lose a little of their juice. The German machine is almost entirely like the cutters used in the beet sugar factories in Europe. It consists of a horizontal disk 1.8 meters in diameter, placed on a vertical axis and having 120 revolutions a minute. In this disk are ten boxes to receive the knives and their frames. Each frame carries two knives placed end to end. It is easier to make the knives in two pieces than in one. A long knife is liable to bend in tempering, rendering it difficult to grind and fasten in its place. Above the disk is placed the cover, on which, in an oblique direction, are placed three double funnels to direct the canes against the knives. In each revolution each knife makes thirty-six cuts, or a total for all the knives of 14,400 sections per minute.

With the French machine, on the other hand, fed at only one point, only 2,880 sections per minute could be secured. Thus the experiments were entirely to the advantage of the German machine, and much of the subsequent success of the diffusion experiments can be justly attributed to it.

* Picol = 135 pounds.

The first part of the experiments having succeeded so well the committee could pass with greater confidence to the second.

In March, 1885, the diffusion apparatus arrived, and the apparatus was ready for trial on the 15th of June. The diffusers, ten in number, were disposed in a straight line, and the cane-cutters were placed above, the cane being delivered to them by an elevator. Each diffuser had a capacity of 13.50 hectoliters. It is cylindrical in form and the discharge gate occupies the entire bottom of the cell. The battery was placed high enough to allow the exhausted chips to fall directly into the wagons by which they were removed to the bagasse yard. After the usual experiences of a new apparatus, viz: the breaking of some of the gates, and a rearrangement of the cutters, on the 20th of June a good trial was made. The chips of 4 millimeters thickness in previous trials had been found too thick for rapid diffusion, and the cutter was adjusted to secure a thickness of only 2 millimeters; but with this adjustment it did not work well. Therefore, for the trial of June 20, the knives were set to give the chips a thickness of 3 millimeters.

From 7 a. m. to 6 p. m. eighty-two cells were charged, each one with 600 kilograms of chips. Everything went well. In a period of sixty-seven minutes ten cells were emptied. The temperature could be carried to 95° without difficulty. The cooled diffusion juice showed a density of 7°.6 B.; that of the mill juice being 8°.4. The work was continued into the night, and in all one hundred and fifty diffusions were made. On the 21st of June 103,800 kilograms of cane were worked in one hundred and seventy-three diffusions, and 600 liters of juice were taken from each diffuser of a mean density of 6°.14 B. The exhausted chips still contained .84 per cent. of sugar. With such a dilute juice it was not possible to continue to work with diffusion. Four boilers of 140 square meters of heating surface, of which three were heated with bagasse and one with wood, did not furnish enough steam, and in consequence the pump of the triple effect would not work. The fifth boiler at the time was undergoing repairs. It was found also that the calorisators developed too much heat, and that the steam traps connected with them did not work regularly. It could also be foreseen, and the subsequent experiments established the fact, that with ten diffusers only, a too dilute juice would be obtained to enable one to say that work with diffusion would prove profitable. Nevertheless it was evident that with a battery with a greater number of cells this fault could be avoided. It was noticed also that the coefficient of purity of the diffusion juice was higher and the proportion of glucose less than in the juice from the mill.

After the workmen were more accustomed to the machinery it was possible to work faster, so that on the 2d of August 83,709 kilograms of cane were worked in nine hours and forty-five minutes, which corresponds to 197,400 kilograms in twenty-three hours. It may be said, therefore, that worked at its full capacity, the battery would be able to use 200,000 kilograms in twenty-four hours.

For the purpose of determining the change in the character of the juice in its progress through the battery a small quantity of it was taken at a given moment from each diffuser.

On analysis the following results were obtained:

Diffuser—	Specific gravity.	Degree Brix.	Sugar.	Purity.
			Per cent.	
No. 1	1,0005	0.15	0.11	73.33
No. 2	1,0025	0.7	0.57	81.43
No. 3	1,0050	1.5	1.28	85.33
No. 4	1,0110	2.8	2.54	90.71
No. 5	1,0170	4.3	3.97	92.32
No. 6	1,0245	6.2	5.89	95.32
No. 7	1,0335	8.5	8.14	95.76
No. 8	1,0450	11.2	10.76	96.07
No. 9	1,0530	13.1	12.19	93.05

The sudden fall in the number denoting the purity coefficient in the ninth cell cannot be explained otherwise than by the difference in the quality of the cane.

For the purpose of being assured of the degree of density to which the juice could be brought when the number of diffusers was increased the following experiment was made. At a given moment in the midst of the work the juice was no longer drawn off, but was retained until the diffuser No. 1 which we will now call No. 11 was filled anew with chips and instead of extracting the juice from No. 10, it was forced into No. 11. In a like manner were treated Nos. 12, 13, 14, 15, and 16.

Following are the results:

Diffuser—	Specific gravity.	Degree Brix.	Sugar.	Purity.
			Per cent.	
No. 1	1,0007	0.19	0.14	73.68
No. 2	1,0025	0.60	0.43	80.68
No. 3	1,0060	1.60	1.32	82.50
No. 4	1,0120	3.60	2.46	82.50
No. 5	1,0170	4.40	3.95	89.32
No. 6	1,0240	6.10	5.65	92.29
No. 7	1,0350	8.80	8.02	91.12
No. 8	1,0460	11.50	10.35	90.12
No. 9	1,0570	14.50	12.77	91.21
No. 10	1,0600	14.80	13.53	91.42
No. 11	1,0600	14.80	13.09	90.07
No. 12	1,0610	15.80	13.61	90.73
No. 13	1,0620	15.20	13.75	90.45
No. 14	1,0620	15.20	13.86	91.12
No. 15	1,0650	15.90	14.85	93.40
No. 16	1,0655	16.90	14.85	92.81

At the time of making these experiments the juice from the mill from cane of the same kind had a specific gravity of 1.079, or 19 Brix and 16.94 per cent. sucrose. Its purity quotient was 89.16. From what precedes it can be concluded that with a battery of sixteen cells the juice could be made 20 per cent. stronger than with ten cells. This method of work, however, did not permit of the estimation of the quantity of sugar remaining in the exhausted chips. With the ordinary working of the battery the same day the sugar content of the discharged chips was .57 per cent.*

From all the experiments made the committee is able to declare that the process of diffuson applied to cane presents no difficulty; that it is demonstrated that with small diffusers with an inferior opening of a diameter equal to that of the cell the working is extremely convenient and gives rise to no change in the juice. The fact is that the dilution of juice does not appear to be greater than in Europe with the sugar beet; that the process of diffusion presents many advantages, consisting in a better extraction of the juice than with mills, and in the obtaining a juice more pure; that the danger of breaking the mills is avoided; that the greater consumption of fuel by reason of the greater dilution of the juice and the increase of expense resulting therefrom is not too considerable in presence of the advantages of the extraction of the sugar which the method offers.

The committee had intended to confirm its affirmation by treating a few thousand picols of cane by diffusion and comparing the yield of sugar with that obtained by

*NOTE.—I desire to call attention to the fact which the Java committee seem to have overlooked, viz: that by a continuation of the work performed by them so as to secure sixteen saturations of the diffusion juice they did not imitate the conditions of the regular work of the diffusion, but only the conditions of first beginning the charge of the battery. The diffusion liquid in the experiment above described was brought six times at least into contact with perfectly fresh chips, while with regular work it is only brought once into such contact. Naturally the increase in density by the method followed would be more rapid than in ordinary work. The experiment described does not have, in my opinion, the importance which the Java people attach to it.—H. W. W.

the ordinary method of extracting the juice. This idea, however, was abandoned by reason of the difficulties attending the carrying it out. The first difficulty was the exact weighing of the cane; the second, the exact weighing the charge in the cell. It was also extremely difficult to keep the product in the factory distinct from that of the mill. There was still another difficulty due to the extremely variable quality of the cane. After having recognized all this the committee thought it better to judge the process of extraction of the juice by the figures concerning the two methods obtained by the analyses and to leave aside the transformation of the juice into sugar. The yield of sugar is too dependent on the method of work followed in the factory to serve as a means of comparison. Confining itself, therefore, to the extraction of the juice it gives the figures to follow. A few multiple pressure experiments were made with the mill and the mean result was:

	Per cent.
Juice	73.95
Bagasse	26.05
	100.00

The juice and bagasse on analysis gave the following results:

	Juice.	Bagasse.
	Per cent.	*Per cent.*
Sucrose	16.84	9.56
Water	81.50	42.47
Glucose and not sugar	1.60	.....
Cellulose &c	.....	48.17
	100.00	100.00

For the juice.

73.95 × 16.84	12.45 per cent. sucrose in cane obtained.
73.95 × 81.50	60.27 per cent. water in cane obtained.
73.95 × 1.60	1.23 per cent. glucose in cane obtained.
	73.95

For bagasse.

26.05 × 9.36	2.44 per cent. sugar in cane lost.
26.05 × 42.47	11.06 per cent. water in cane lost.
26.05 × 48.17	12.55 per cent. cellulose, &c.
	26.05

One hundred parts of cane contain, therefore: Of sucrose, 14.89 parts; of water, 71.33 parts; of cellulose, &c., 13.78.

Thus with a remarkably good pressure there was lost in the bagasse 2.45 parts of sugar for each 100 parts of cane, or 16.37 per cent. of the quantity of sugar contained in the cane.

From the analyses made of the various products of diffusion the following deductions are made:

	Per cent. of cane.
Sugar in discharged chips (seven analyses)	.84
Sugar in waste waters (six analyses)	.05
Total sugar lost	.89

Difference in favor of diffusion 2.44 — .89 = 1.55 per cent. of cane.

It must be noted that these figures are not the most advantageous to show the merits of diffusion. The mills do not always give 74 per cent. of juice. There is always in the bagasse more than 9.36 per cent. of sugar. If for the average pressure 70 per cent. is counted it will be nearer the truth. The loss by diffusion is taken from the working of a battery which does not fulfill the conditions of good procedures.

DISCHARGED CHIPS AS FUEL.

Whatever judgment may be passed on the greater or less advantage of the process of diffusion there remains a difficulty which has not been removed, viz: the drying the exhausted chips. It is well recognized that they do not dry as readily as the bagasse of the mills. When the chips leave the diffusers they contain about 90 per cent. of water; the bagasse of the mills contain, only about 43 per cent. After the bagasse has been dried in the yards as it comes to the furnace it still contains about 23 per cent. of water. The bagasse from the mill will burn without any difficulty in bagasse furnaces.

Therefore it is necessary that the chips lose 47.5 per cent. of water before they can be used in a bagasse furnace of ordinary construction. With a Selwig & Lange press the content of water in the chips was reduced to 82 per cent. With a small laboratory press to 67 per cent. This result permitted the hope of being able to reach a better result with a very strong press.

Drying the chips in the bagasse yards succeeded better. A very good fuel was obtained, but two full days of good sunshine were necessary and the layers of chips had to be constantly turned. They had also to be spread in very thin layers on the ground. Even with a very thin layer the chips were only dried on the upper surface, those below very little. A large bagasse yard would be required to dry the chips and more skillful coolies would be required for the work, and in addition it would be necessary to have fine weather and good sunshine.

Remembering that linen in European countries was dried very quickly by centrifugal force some experiments were made to dry the chips in the centrifugal machines, but the results were negative. It was only after twenty minutes with 800 to 900 turns per minute that the content of water in the chips was reduced to 84.62 per cent.

Having thus given a résumé of the results of the experiments of 1884 and 1885, we see that there is no difficulty in cutting the cane in convenient form for diffusion, and that it requires only a very small force to drive the machine. Furthermore, that in the process of diffusion the generation of glucose, so much feared, did not take place, and that after the workmen had had a little practice in the manipulation of the machinery the progress of the work is easily conducted and in a perfectly regular manner. The experiment with sixteen diffusers described above has furthermore taught us that in order to arrive at the least possible dilution of the juice and the greatest possible exhaustion of the chips the battery should be composed of more than ten diffusers. It is therefore a matter of great interest to continue the experiments with a larger battery during the next campaign.

M. Lucassen told me that the recommendation of the committee had been adopted by the Planters' Association and that two additional cells were being placed in position for the coming campaign. The builders of the battery, the Sudenburg Company, kindly gave me a drawing of the plan of the plant, which is shown in Fig. 17.

The concluding part of the report gives a record of the amount of money raised by subscription and the amount expended for the various items:

	Florins.
Total amount of contributions with accrued interest was	73,452.79
The expenditures to the end of September, 1885, were	70,453.87
Balance	2,998.92
Bills outstanding not paid	17,098.92
Deficit	14,100.00
For the prosecution of the work during 1886 it was estimated that there would be required	14,200.00
Total sum to be raised by subscription for 1886	28,300.00

The report concludes with a record of all the analyses made during the progress of the experiments. But as the results of these analyses have been summarized in the body of the report, I do not think it necessary to give them in detail. It is evident, however, that, from the money and labor that the Java planters have devoted to their experiments, they are very much in earnest and have a lively sense of the losses entailed by the old processes.

In this undertaking, so bravely begun and carried on in such a business-like and scientific way, are taught many valuable lessons to those engaged in similar investigations.

The Java planters have found out, what the Department of Agriculture had long since learned, that the conduct of such experiments is much more costly than the first estimates show, and that the results obtained are more valuable for the aid they give to subsequent work than for any practical significance which they possess in themselves.

THE TECHNOLOGY OF CARBONATATION.

The experiments made by the Department, both in the laboratory and on a large scale at Ottawa, established the truth of the theory of the depuration of diffusion juice by the process of carbonatation. The juices expressed from cane by mills are of such a nature that when their free acids are neutralized by alkalis and the temperature raised to the boiling point the greater part of the albuminous impurities rise to the surface in the form of a thick scum, which is easily removed. If now the juices be allowed to stand for some time, the heavier mineral impurities and the insoluble salts of lime which have been formed subside and can be removed either by decanting the juice or passing the whole through a filter press. But even with the most successful manipulation the juices obtained by the process are not quite transparent, but contain a certain amount of flocculent matter, which is retained with difficulty by filter cloths and often not entirely removed by passing it over bone-black. Before the experiments of the Department were made it was feared that the addition of 1½ to 2 per cent. of lime to the mill juices, and the subsequent removal of the excess by treatment with carbonic acid at a somewhat elevated temperature, would either destroy the glucose which the juice contained or form with it decomposition products which could greatly injure both the color and flavor of the molasses produced.

Happily both the laboratory experiments and those made on a manufacturing scale showed that, with proper treatment, these fears were groundless. A strong corroboration of the statements made concerning the experiments of the Department is found in the result of the work with carbonatation at Almeria, Spain, where a whole crop of cane has been worked into sugar, using this process for the purification of the juice. In this work not only was the carbonatation performed at a very

high temperature, but it was repeated, and both of these operations failed to destroy all the glucose or render the molasses valueless. It is true that by double hot carbonatation a portion of the glucose is destroyed, but, as our experiments have shown, a single carbonatation made at a low temperature is entirely sufficient to produce a juice limpid and pure and ready for treatment in the triple effect without any further manipulation. Diffusion juices in fact being more dilute than those from the mill and containing a less proportion of coagulable matter are not suited for purification in the ordinary way. For the proper treatment of such juices carbonatation is absolutely necessary. It is to be commended, both on account of the pure juice which it affords and because of the saving of sugar in the scum and sediments which it effects. The results of the experiments at Ottawa, cut short as they were by an untimely and severe frost, were, nevertheless, encouraging. If such good results could be accomplished with such difficulties to be overcome there is every encouragement necessary to give the technology of the process a careful study, so that the forms of apparatus best suited to the purpose may be brought to the attention of our sugar planters. It was with this object in view that I determined to devote so much time to the study of the process of the purification of the juice and to the collection of the data and drawings which would enable me to place the results of this study in a proper shape before the sugar manufacturers of the country.

PRODUCTION OF THE CARBONIC ACID.

The carbonic acid used in the saturation tanks is derived from a lime-kiln of peculiar construction. The requisites of a first-class kiln for this purpose are that it shall have abundant capacity to produce the gas needed, that it shall be durable and refractory, and that the arrangement of its interior shall be such as will permit the regular dropping down of the upper contents as the burned lime is removed from below. A lime-kiln which will furnish gas for a factory working 200 tons per day should have about the following dimensions: Greatest inner diameter 2 meters, top diameter, .75 meter, height 8 meters. The plan of such a furnace showing the details of its construction, kindly given me by the Sangerhaüser Maschinenfabrik, is shown in Fig. 18. The section A B shows the shape of the kiln. Its interior contour forms a double cone whose bases are joined at E F, about 1 meter from the bottom of the structure. The object of the contraction in the diameter below is to keep the burned lime from falling, directly the external portions of it are removed. Were it not for this contraction it would often be impossible to get at the burned lime in the center of the kiln. As soon as the exterior portions were removed those fragments immediately above would fall down and thus cut off access to the center. The interior of the kiln is built of fire-brick and the whole is encased in a covering of thin boiler iron. Between the iron cover and the fire-brick interior is

a narrow space filled with some highly non-conductive substance. In kilns of less complete structure the exterior walls are built of stone or common brick, and instead of an iron jacket there are four broad iron bands placed without the structure.

Some small openings are seen in the walls of the furnace. These serve for the introduction of iron bars to loosen the limestone in the furnace where, for any reason, it fails to fall when the bottom layers are removed. These openings are closed externally with an iron hood. The furnaces, of which there are three, are placed outside the kiln. One of these is shown at E G in the section A B, and the plan of all three is shown in the section E F. These furnaces are used generally only at the beginning of the campaign, the coke nearly always being fed to the kiln along with the limestone. The coke is fed to the furnace from the top through the conical aperture shown in the section A B, and shown itself in section C D. The openings, through which the burned lime and ashes are removed, are shown in plan in the section G H. The center of the bottom of the kiln is raised so that there is an inclination of the floor towards the exterior. This allows the lime to be withdrawn with ease. The limestone is broken into fragments of from 4 to 10 square centimeters, and being mixed with a proper quantity of coke (about 10 per cent.) is elevated in wagons to a platform and dumped into the kiln through a trap-door at the top of section A B.

The pipe leading to the gas-pump is also shown in the diagram. In many kilns this pipe, instead of being attached to the top, enters the kiln at a distance of 1 or 2 meters from the top. By this arrangement the suction of the gases through the upper and cooler portion of the charge is avoided. The pipe and pump should be of sufficient capacity to produce all the draft necessary to keep the contents of the kiln at the proper temperature. The fittings of the kiln should be, as nearly as possible, air-tight. The door at the top must fit evenly in its frame, and especial care must be taken that the walls of the structure have no air-holes. All the air that enters the kiln should do so through the furnaces or lime-holes at the bottom. Any air that enters through the door at the top or through the openings left for loosening the impacted charge of the furnace dilutes to that extent the carbonic acid passing to the factory and diminishes the efficiency of the carbonating tanks. A well constructed kiln, heated gradually and carefully manipulated, will last through many campaigns. The kilns are always placed outside of the manufactory building for convenience of access and to avoid any danger of fire. The kiln must be well protected from rain, which, falling on it while hot, would prove very disastrous. If, by any accident, the pump should cease working, the door at the top can be left open and the kiln kept in combustion by the draft thereby created.

The fire in the kiln should be started four or five days before the manufacturing season begins, so that at the commencement of it car-

bonic acid, supplied in sufficient quantity and of the maximum degree of concentration, may be in readiness.

The relative position of the limekiln and its connection with the rest of the machinery for defecating the juice is shown in Fig. 19, for which I am indebted to the Sudenburg company, of Madgeburg. In the plan of the apparatus is seen a section of the base of the kiln with hearths for the reception of the fuel (when it is supplied in the lateral furnaces below). In the upper right-hand corner of the plan for the kiln is found the position of the apparatus to elevate the limestone and coke. Immediately below this is the tank furnished with a stirrer in which the lime is slaked. The machinery for driving the elevator and slaking the lime is driven either by a belt from the main shaft or, better, by a small engine, the position of which is indicated. To the left of this machinery, and immediately without the shed of the kiln is found the

WASHER OF THE GAS.

The washing apparatus has a double object, viz: first to free the gas from any ammonia, hydrosulphuric acid, or other injurious gases soluble in water which the mixed gases issuing from the kiln may contain, and, second, to cool the gas which comes from the kiln at a very high temperature. The volume of aeriform matter which comes from the kiln is a mixture of various gases. These are principally carbonic dioxide, the result of the combustion of the carbon and decomposition of the limestone at a white heat; next a large percentage of atmospheric air, which enters the kiln in excess of the requirements of combustion, and this excess escapes unchanged; next must be mentioned the nitrogen, which is left by the union of the oxygen of a certain portion of the entering air with the carbon of the coke; next in importance is the carbonic oxide coming from incomplete oxidation of some of the combustible matters; then in smaller quantities may be found ammonia,* free hydrogen, marsh gas, olefiant gas, hydrosulphuric and sulphurous acids derived from impurities in the coke. With very pure, well-burned, and well-washed coke, the quantity of these last named gases is extremely minute.

The washing removes from these mixed gases the ammonia, hydrosulphuric and sulphurous acids. Owing to the very low specific heat of gases and the high degree in which water possesses that property a very small volume of water is capable of cooling to the required temperature a very large volume of gas. The gas should not enter the carbonatating tanks above a temperature of 100° C. Various devices are used to effect the washing and cooling. The cooler is a simple tank furnished with a central tube for the gas from the kiln and one for the water, and exit tubes for the gas going to the pump and for the water going to the sewer. The gas may be made either to bubble through a layer of water or to meet, on its upward course through the washer, a descending spray of water. The cooling of the gas also largely dimin-

* In combination or dissociated.

ishes its volume and renders it more easily handled by the pump. The construction of a washer is an extremely simple matter, and yet great care should be used to secure a thorough ablution in the preparation of the gas.

ARRANGEMENT OF THE APPARATUS FOR CARBONATATION AND SULPHURIZATION OF THE DIFFUSION JUICES.

The apparatus necessary for the treatment of the juices preparatory to their entrance into the triple-effect pan consists of the following pieces:

(1) Pump for bringing the carbonic acid from the kiln and forcing it through the juice.

(2) Carbonatation tanks furnished with perforated pipe connected with pump for distributing the gas, steam pipes for heating the juice toward the end of the operation, cover and chimney to direct the excess of gas through the roof and into the open air, and valves, plugs, &c., used to control the filling and emptying the tanks.

(3) Pump or *monte-jus* to force the juice into the tanks in case the tank receiving it from the diffusion battery is not high enough for this purpose.

(4) Reservoirs to hold the cream of lime, carefully prepared and of an uniform density, so that the quantity of lime added to juice may be known from its volume.

(5) Pump or *monte-jus* to send the carbonatated juice through the first set of filter presses.

(6) One set of filter presses for separating the precipitated lime and other insoluble impurities from the juice.

(7) A second set of saturation tanks, in which the juice is treated with sulphurous acid. These are similar in every respect to those used for the carbonatation.

(8) Sulphur furnaces in which is generated from brimstone the sulphurous acid required for the second saturation.

(9) Air-pump to force the air into sulphur furnaces and the sulphurous acid made thereby into the saturation tanks.

(10) A second set of pumps or *monte-jus* to send the juice saturated with sulphurous acid through the filter presses.

(11) A second set of filter presses, used for the juice coming from the sulphurizing tanks.

(12) A system of bag filters, if deemed necessary, for the final filtration of the juice before it passes to the triple effect.

The arrangement and connection of the apparatus for the purification of the juice of 200 tons of cane per day is shown elaborately in Fig. 20, for which I desire to thank Herr R. Riedel, director of the Hallesche Maschinenfabrik, Halle an der Saale.

The plan of the ground floor shows the connection of the apparatus with the limekiln, the positions of the gas pump, the tanks for mixing

and receiving the cream of lime, a section of the *monte-jus*, and the position of the three filter presses to be used for the second saturation (with sulphurous acid).

The *monte-jus* for the first saturation for forcing the juice through the filter presses are each of 2,500 liters capacity, with complete armatures and a high stand-pipe for control from the carbonatating floor (see position of one of these *monte-jus*, in sections through C P, lower left-hand corner). The carbonic acid pump has a steam cylinder of 350 millimeters and the gas cylinder of 600 millimeters diameter, and the length of the stroke is 550 millimeters. It has a double fly-wheel for regulating the stroke, and all its valves and other parts exposed to the acid are made of material not attacked thereby. Particular stress is to be laid on the construction of the gas pump, for if that gets out of order the whole process must stop until the damage is repaired.

The apparatus for slaking the lime and preparing the cream of lime consists of a double tank of iron, a compartment furnished with a sieve outlet, which retains all the large particles and allows only the pure lime mixture to flow through, and a tank furnished with a stirring apparatus, in which the cream of lime is thoroughly mixed and brought to the proper density. At the side of this is a pump to elevate the prepared cream to the tanks, whence it flows into the juice as required. The arrangement of all this apparatus is shown in the sections through E F at the bottom. The floor plan of the first story* shows at the bottom, beginning at the left, the spiral stairway connecting with the ground floor, the tops of the *monte-jus*, and the furnaces for generating sulphurous acid. At the top, in the same order, are the four carbonatating tanks, next the three tanks for saturation with sulphurous acid, and to the right the five filter presses for the first saturation.

The pans for the first saturation each have a capacity of 2,500 liters of juice with a foam space 1 meter deep. The tubes for distribution of the carbonic acid are easily removed for cleaning. The steam pipes are of copper and are placed near the bottom and side walls of the pan. The top of the pan is covered and a flue connects it with the ventilating chimney, through which the excess of gas escapes to the open air. Each one is provided with valves, stop-cocks, and connections complete for charging with juice and discharging. Near the top is also a steam pipe running entirely around the pan, perforated with numerous openings to be used when troublesome foaming occurs. The escaping steam jets, directed inwards and upwards, cut the foam and prevent it from being drawn into the ventilating flue.

The three pans for saturation with sulphurous acid hold each a charge of 3,500 liters with a foam space 400 millimeters deep. The arrangements of pipes, valves, connections, ventilators, &c., are exactly the same as for the preceding. The perforated pipes, however, for distributing the sulphurous acid are somewhat differently arranged, so as to

* Lower right-hand corner.

give exit to the gas in more numerous and finer bubbles. The filter presses for the first saturation are five in number. Each has twenty-four chambers fed from a central tube. On a tramway under the presses is placed a wagon to receive the press cakes as they are removed from the cloths and transport them without the building, whence they are dropped into a cart and removed.

The section through E F shows the relative positions of the filter press, and wagon. The three presses on the ground floor used for the second saturation (with sulphurous acid) are smaller, containing only eighteen chambers, and the space for the formation of the cake is much thinner. This results from the fact that the amount of solid matter to be removed by the second filtration is much less than with the first. The section G H shows the relative positions of the sulphur furnaces, the saturation pans for sulphurous acid, and the filter presses for the second filtration. No *monte-jus* or pump is required for the second filtration, the force of gravity being sufficient to force the liquid through the press. The quantity of solid and precipitated matter is so small as to allow this disposition of the presses. The distance from the bottom of the saturation pan to the top of the press is nearly 2.5 meters. By a slight change in the position of the saturation pans this distance, and consequently the pressure in the presses, could be considerably increased.

The section A B longitudinally through the center of both the ground floor and first story affords an *ensemble* of the chief portions of the apparatus. Instead of *monte-jus* for the elevation of the liquid and feeding the presses, a pump is often used. Ordinary juice-pumps will not serve for this purpose. Their valves do not work well in the thick mud, which rapidly settles to the bottom of a tank of juice just from the carbonatating pans. For feeding the presses, also, a pump must have some kind of a regulator or safety-valve to prevent the rupture of the filter cloths. Such a mud pump is much used in Germany, and by some manufacturers is preferred to *monte-jus*. A description of this pump will be given further on. A careful study of the plan of the saturation apparatus just given will show that it is most admirably adapted for the purpose intended. It will be noticed also that it differs in many respects from the processes in use in beet-sugar factories. The first point of difference is in using but a single carbonatation. Cane juice is much more easily purified than beet juice, and extensive experiments, both in the laboratory and on a large scale, have shown that one carbonatation is amply sufficient. This carbonatation should be made at as low a temperature as possible. When all the lime but about 0.02 per cent. is precipitated, the temperature should be carried rapidly to the boiling point, and the juice sent at once to the filter presses. If the carbonatation is carried farther than this, the precipitated impurities are likely to be set free and the work has to be done over. The next important variation in the process consists in the extremely efficient ap-

paratus for saturating the juice of the first carbonatation with sulphurous dioxide. This juice, it must be remembered, is still hot. It requires, therefore, a much more thorough exposure to the sulphur fumes than a cold juice. By the apparatus which is represented in the plan the saturation can be made as thorough as desired. A double advantage comes from the use of the sulphur apparatus. In the first place, the alkalinity remaining from the carbonatation is removed, and in the second place the coloring matters of the juice are almost entirely discharged. So complete is the purification and bleaching of the juice by the processes described, that the use of bone-black for the production of a white sugar is unnecessary. In this item, also, there is a great saving of expense. I shall take occasion in the general conclusions derived from the present investigations to point out the immense advantage which this method of clarification has over the one which is generally in use. I desire to say here, however, that it can be applied also to mill juices, and with the happiest effects. The factory in Java at Djattiwangie has employed with the greatest success the process of double carbonatation, identical with that used in beet-sugar factories. The method has given entire satisfaction.

The method is commended by the scientific and rational principles which underlie it, by the ease with which the processes are carried out, by the pure and limpid character of the juice which it affords, and by the great saving of sugar which it effects in the scums and sediments produced by the ordinary process of depuration.

The quantity of sugar which is annually thrown away in the scums and sediments of the old method is often enough, if saved, to convert a losing into a prosperous campaign.

I therefore cannot urge too strongly on all our sugar planters to give a respectful and earnest consideration to the results of the investigations of the Department laid before them in this report.

I have already referred to the installation of a saturation apparatus in which, instead of *monte-jus*, a pump is used. A *monte jus* is certainly cheaper and requires less steam for its operation than a pump, but it requires more attention, and, by the condensation of the steam at the point of contact with the liquid in the *monte-jus*, quite an addition to the amount of water to be evaporated takes place. Great care must also be exercised to prevent the steam from entering the filter press where it would do a great deal of damage and cause much trouble. All of these disadvantages are removed by the use of a properly constructed pump. One of the best pieces of apparatus in use for this purpose is Kroog's automatic Schlamm-pump, shown in Fig. 21. This pump stands on a heavy ground plate which renders the whole apparatus independent of the foundation. The machine is so arranged that it requires no attention whatever. By an ingenious device the motion of the pump is entirely automatic. As soon as all the filter presses fed by the pump are full the pressure is increased until it acts on an automatic regula-

tor by which the motion of the pump is stopped. As soon as one of the presses is cleaned and again connected with the pump, the latter, at once of its own accord, is set in motion. Thus the degree of pressure on the filter cloths is always prevented from reaching a point which would cause their rupture. The pump is provided with a double steam and pump cylinder. A pump capable of handling the juice from 250 tons of cane has the following dimensions:

Diameter of pump cylinder 150 millimeters, length of stroke 400 millimeters, diameter of steam cylinder 250 millimeters, diameter of suction and filter press pipes 125 millimeters, turns of fly-wheel per minute 25; dimensions of space occupied by pump, length 2,700 millimeters, breadth 1,400 millimeters, height 2,650 millimeters, weight 4,200 kilograms.

The arrangement of the automatic pump and filter presses is shown in Fig. 22.

KROOG'S FILTER PRESSES.

The construction and working of the filter presses are items of great importance in the manufacture of sugar. The filter presses which are outlined in the plan (Fig. 22) are the improved form invented by Herr Kroog. There are two methods of supplying the liquid to be filtered to the chamber of a press. The most usual way is by an opening passing through the center of the plates. The objection to this method is the difficulty of fitting the filter cloths to this opening. In the Kroog press the feed pipe is attached laterally to the chambers, thus avoiding the difficulty mentioned. Another important point in connection with the working of the filter press is the method of displacing the sweet liquid with which the cakes are saturated when the press is ready for cleaning. To throw the cakes away containing so much sugar would be a wasteful procedure which in scientific and economic sugar manufacture could find no place. Two methods of desucration are employed. In the one the cakes are taken from the chambers of the press and thrown into a mixer where they are beaten to a cream with hot water, and the whole again sent through the press. The resulting cakes are now saturated with a liquid which has a much lower content of sugar than was found in the original product. But the sugar juice which is washed out by this process is very greatly diluted and thus a large increase of evaporation is produced.

The other method consists in treating the cakes, while still in the press, with hot water or steam. This method is extremely simple and, when properly conducted, results in as great a saving as the other. The advantages of the method will be seen at a glance. It effects a saving of time and also of filter presses, mixing machinery, and pump or *montejus*. Its disadvantages are that by carelessness of the attendant an even desucration of the cakes may not be secured. From observation of the working of both methods I am inclined to prefer the latter one.

The best filter press for this work which I have seen is Kroog's, manufactured by the Sangerhaüser Company.

A view of this press is seen in Fig. 23.

The feed-pipe *a* is not in the center but at the lower corner of the press opposite the discharge-pipes. This permits the filtering cloth to be of one piece without any perforation whatever, a very great advantage. The water-pipe, through which flows the warm water for the desuc ration of the cakes, is attached to every alternate chamber at the upper edge, diagonally opposite the attachment of the feed-pipe. The sweet juices which are displaced from the cakes by this device are very nearly of the same density as the original diffusion juice. Thus a troublesome dilution is avoided. The displaced juice flows into the gutter below, which is large enough to hold all the liquid displaced at one operation. It is furnished with a specific gravity scale so that the density of the displaced juice is at once evident. The operation is discontinued when the outflowing water contains only a small percentage of sugar. The press is closed and opened by a swinging screw, allowing one person to perform this manipulation in a few seconds. This is also an advantage over the old method of opening and closing by means of a screw alone. The method of working the press is exceedingly simple. The plates and channels being properly covered by the filtering cloths the press is closed by means of the swinging screw. The valve at *a* is now opened to allow the liquor to enter the chambers from which it passes through the filter cloths, and is discharged through the cocks at the side. As the chamber becomes filled with the precipitated matters the rapidity of the outflow gradually decreases, and when the chambers are quite full, almost ceases. The valve is now closed, and the discharge valve from the gutter *c* opened, and water forced into the spaces thus opened through the valve *b*. As soon as the water begins to flow out of the air valves they must be closed. The pressure of water will immediately begin to drive the sweet juices out of the cakes through the small cocks of the discharge plates, and this process is continued until the liquid in the gutter is reduced to a density previously agreed upon. The valve *b* is then closed. Before opening the press to remove the cakes the gutter must be covered over, the press is then opened and the cakes fall into the cart below. The water of displacement is moved by a small pump which is shown in Fig. 22, upper left-hand corner.

Having explained to Herr Rabe, director of the Sangerhaüser Company, the variations from a beet-sugar installation required for the treatment of cane juices, he, at my request, prepared a plan for the erection of apparatus for the clarification of cane juices, using automatic mud pumps and Kroog's filter presses. The arrangement of this apparatus is shown in Figs. 22 and 24. The apparatus is adapted to the treatment of 250 to 300 tons of cane per day. The filter presses, Fig. 22, and automatic pump are shown in horizontal section. A de-

scription of the pump has already been given. The filter presses are five in number. Each has the following dimensions: The frames are thirty in number, 583 millimeters square. The thickness of the cake space is 25 millimeters. There are thirty chambers covered with perforated plates, the joints of which are made with rubber gaskets. Each chamber is so arranged that it can be thrown out of work without interfering with the functions of the others. In the vertical longitudinal section of Fig. 22 are shown the connections of the feed and discharge pipes, and the displacement pump and pipes with the presses. The displacement pump, double acting, has the following dimensions: The pump cylinder has a diameter of 65 millimeters, and a stroke of 160 millimeters. The diameter of the steam cylinder is 110 millimeters; the pump is furnished with an air reservoir, manometer, and safety valve. Its connections with the presses are shown in the elevation of Fig. 22. For a daily consumption of 150 to 200 tons of cane the number of filter presses can be reduced to three or four.

The part of the apparatus used for saturation with sulphurous acid is represented in Fig. 24, plan and elevation of longitudinal and cross sections.

The sulphur furnaces are made of cast iron, 1,150 millimeters in length and 500 millimeters in diameter. The double furnaces are used so that one may always be in action in case the fire in the other is extinguished accidentally or intentionally.

The sulphur fumes forced upward by the current of air from the air-pump pass through a tube surrounded by a water jacket, by which they are cooled to the proper temperature. There is also a device by which the sulphurous acid is washed free of any sulphuric acid during this transit. The position of the air compressor is shown in the longitudinal elevation. To the left of the furnaces is seen a cylinder of cast iron, 2,900 millimeters in length. This cylinder is filled with water and a pipe connecting with the outlet tube of the furnaces extends nearly to its bottom. In case the sulphurous acid is shut off from the saturators it escapes through this pipe and is conducted away by the tubing descending to the left as shown in the diagram. This arrangement prevents the fires in the furnaces from being extinguished when the gas is shut off from the saturation pans. Sulphur is placed in the furnaces through a door and ignited with a piece of red-hot iron. The door is then closed air-tight by means of an asbestos gosket.

The saturation pans are three in number, each holding 2,700 liters of juice and having a foam space 250 millimeters high. The bottom is slightly inclined towards the opening of the discharge pipe. The cover is riveted on the pan, being furnished with a man-hole closed by a hinged door with rubber gaskets and fastened air-tight by a screw. The sulphurous acid and heating steam-pipes are of copper, the latter having 2.17 meters square heating surface and weighing 25 kilograms per

meter square. All the pans are fitted with inlet and outlet discharge valves, stop-cocks, and fixtures complete.

This arrangement of the sulphurizing apparatus is extremely convenient and effective, permitting a thorough saturation of the juice and preventing any escape of the sulphurous acid into the working rooms of the factory.

The filter presses for the sulphurous saturation are three in number, Kroog's patent twin chamber pattern. They permit a double filtration of the juice in one operation. They are placed 3 meters below the saturation pans, which position permits the filtration of the juice without using a pump or *monte-jus*. The thickness of the sediment space is 5 millimeters. This is amply sufficient for the small amount of precipitated matter in the juice of the second saturation. These presses are especially adapted to this kind of work and are much superior to the ordinary filter press for the purpose intended.

ESTIMATE OF COST OF APPARATUS FOR A COMPLETE INSTALLATION FOR EXTRACTION OF SUGAR FROM SUGAR-CANE BY DIFFUSION AND FOR DOUBLE SATURATION OF THE JUICE WITH CARBONIC AND SULPHUROUS ACIDS.

Having now briefly, but I hope intelligibly, studied the forms of apparatus suitable for carrying on the processes described, it will be of interest to give the approximate cost of the whole plant. It will not be expected that the exact figures will be given, because there are many parts of the apparatus, such as the peculiar adaptation of the parts for the application of sulphurous acid, which have not yet been constructed in the form desired. The prices given are those of the European makers and do not include packing or freight on board steamers.

Cost of diffusion battery.

Battery of 16 cells (entirely cylindrical interiorly) arranged in a circle, each cell of 18¾ hectoliters capacity, of 1,000 millimeters diameter, discharge gate of the entire area of the base of the cell, with hydraulic closure and all the levers necessary to work the valves from the upper platform (approximate price)	$5,440 00
Sixteen calorisators for the battery of 3 square meters of heating surface, with brass tubes, with circular face temperature indicators and steam valves complete	2,320 00
Tubes and valves uniting the diffusers and calorisators, 100 millimeters in diameter, tubes and valves for manipulating with compressed air and all the necessary fixtures and connections complete	3,065 00
Elevator for exhausted cossettes, with all the fixtures complete	600 00
Measuring tank for the juice issuing from the battery, with pipes and valves and float indicator	75 00
Air compressor, with cylinder 230 millimeters in diameter and a stroke 350 millimeters in length, driven by a belt from the transmission shaft	400 00
Reservoir for air 40 hectoliters capacity, with pipes and cocks	160 00
Pulleys, shafts, bearings, &c., for transmission of movement to the several parts of the machinery	1,100 00

Iron frame-work and entire support for battery, calorisators, air and measuring tanks, &c	$1,360 00
Cane-cutter, with horizontal disk, multiple knife frames, 300 knives, pulleys, wheel work and frame complete, ready for attachment to transmission, and one extra cutting disk	1,816 00
Elevator for conveying rondelles from cutter to central feed funnel above the battery, iron frame-work and buckets with pulleys and bearings ready for attachment to transmission shaft	900 00
Central swinging funnel, with gutter for charging the diffusers, with supports	180 00
Total estimated cost of diffusion battery and cutter without foundations, buildings, or belting	17,416 00
From which 10 per cent. will be deducted by payment of cash on reception of machinery	1,741 60
Net cost	15,674 40

This is the cost of a first-class battery with all the pipes conveying juice of copper, and of 16 cells adapted especially to the handling of cane chips.

A battery of 12 cells, with cutter, iron pipes, and less elaborate construction, could be had about $5,000 cheaper.

Cost of saturation plant.

Four saturation pans for carbonic acid substantially as described in the text of this report	$1,700 00
Measuring tank for cream of lime	35 00
Two *monte-jus*, each of 2,500 liters capacity, with piping, valves and alarm	500 00
All the castings for a limekiln of the structure and dimensions described in the text	775 00
Apparatus for elevating the limestone and coke, apparatus for washing and cooling the carbonic acid	182 50
Escape valve for carbonic acid when not needed in saturators	40 00
Double acting carbonic acid pump of best pattern and structure, of the dimensions described in the text	1,200 00
Apparatus for slaking the lime, straining it, and mixing the cream of lime in uniform and proper consistency	300 00
Pump for sending cream of lime to the measuring tank	115 00
Apparatus to receive juice from saturating pans	225 00
Pulleys, shafts, &c., for transmission of movement	100 00
Piping, cocks, valves, &c., necessary to connect together the several pieces of apparatus, and the whole with the carbonic acid pump and limekiln, with all necessary fixtures ready for work	800 00
The wrought-iron T beams and columns for supporting the saturation apparatus	300 00
Total cost of plant for saturation with carbonic acid, not including foundation or buildings	6,405 50
Discount of 5 per cent. cash payment	320 28
Net cost	6,085 22

But if, instead of the *monte-jus*, an automatic pump is employed to feed the filter presses, the total cost is	$7,190 50
Less discount	359 53
And net cost	6,830 97

Cost of installation of filter presses for treatment of juice from saturation with carbonic acid.

Four Kroog's filter presses, of thirty chambers each, substantially as described in the text	$2,400 00
Twenty-four sets of filter cloths for the above	310 00
One displacement water pump as described	185 00
Pipings, valves, &c., connecting the presses together, and with the mud pump or *monte-jus*	130 00
Four hoppers for receiving cakes from presses	165 00
One iron dumping truck to receive cakes from hoppers and transport them on a tram without the building	55 00
Total cost without foundations, supports, tramway, or building	3,345 00
Discount offered of 5 per cent	167 25
Net cost	3,177 75

Cost of saturation with sulphurous acid.

Two sulphur furnaces as described in the text	$250 00
Cocks, valves, and piping for furnaces	60 00
One safety and escape valve apparatus	10 00
One air compressor, to feed the furnaces as described	225 00
Three saturation pans as described	860 00
Piping, valves, &c., connecting pans with each other and with sulphur furnaces	150 00
Wrought-iron frame-work for supporting the pans	200 00
Total cost without foundations or building	1,755 00

Cost of filter presses for treatment of juice of second saturation.

Three Kroog's patent twin chamber filter presses, substantially as described	$1,225 00
Eighteen sets of filter cloths for above	330 50
Piping, valves, cocks, &c., to connect presses with each other and with rest of the apparatus	55 00
Total cost without supports, foundations, or buildings	1,610 00
Discount of 5 per cent	80 50
Net cost	1,529 50

Net cost of battery and cutter	15,674 40
Net cost of saturation plant for carbonic acid	6,085 22
Net cost of filter press plant for above	3,177 75
Net cost of saturation plant for sulphurous acid	1,755 00
Net cost filter press plant for same	1,529 50
Total	28,221 87
With automatic pump	28,967 62

The cost of packing this apparatus and freight on board steamer for New York will be about 10 per cent. of cost, or,	
Cost of packing and freight on board	$2,896 76
Freight to New York about the same	2,896 76
Total	5,793 52
Total cost of apparatus at port of New York	34,721 14

Our own manufacturers, I feel quite sure, if they understood the character of the machinery required, would be able to deliver it to the planter at a much less cost. These estimates, as I have said, are for the best quality of machinery that can be made and of a capacity sufficient to work 200 to 250 tons of cane per day.

GENERAL CONCLUSIONS.

A large number of problems which have engaged the attention of those who have studied the question of the manufacture, both from a scientific and economical point of view, appear to be solved by the help of the data which have been collected in the foregoing report.

First among these I may mention the problem of cutting the cane. This process can be successfully performed both by a vertical and horizontal disk, but the preponderance of evidence is altogether in favor of the horizontal disposition of the cutting surface. Experience has shown that the power necessary to cut a ton of cane into chips suitable for the diffusion cell is about ten times less than would be necessary to extract 70 per cent. by weight of juice from the same canes. It is also demonstrated that with knives made of the best material and properly annealed the cutter may be used two or three days without change. But the horizontal position of the disk allows a convenient fixture of the knives by means of frames. Into these frames the knives are fastened as soon as they have been sharpened and the replacement of the frames carrying the dull knives by those provided with the sharp ones is but the work of a few minutes. This disposition of the knives removes the necessity of having duplicate cutters and thus greatly reduces the expense of the installation. Another great advantage of the horizontal disk is found in the practicability of increasing the number of points at which the cane can be presented to the cutting surface. With the vertical disk there is evidently but one such point, while in a horizontal disk as large as that described in the report six separate feed boxes can be used. The capacity of the machine is thus greatly increased. The horizontal disk can be made much lighter than the vertical one and a duplicate disk can be kept on hand to be used in case of accident to the first. The only advantage possessed by the vertical apparatus is found in the circumstance that it can be furnished with a cane carrier similar to those in use with rolls. But this advantage is only an apparent one for when the horizontal cutter is properly placed the canes can be delivered to its feed boxes almost as readily as they can be spread on a carrier. In the cutters of this kind, which have heretofore been used, the dispo-

sition of the *coupe-racine* has been followed, *i. e.*, placing the cutter immediately above the center of the battery. But when I pointed out the disadvantages of this arrangement to constructors of the cutters they at at once recognized the mistake of the location. The proper location of the cutter is one which will bring the upper surface of the cutter level within the surface of the ground or a little below it. This is readily accomplished by digging a pit which will receive the compact frame of the machine with its driving machinery and box for delivering the chips to the conveyor. The tops of the feed boxes are thus at a convenient height for receiving the canes directly from the hands of the workmen. By placing the belt which drives the cutter in a trench and making the horizontal conveyer which carries the chips to the elevator pass entirely below the surface of the ground, it will be easy to unload cane carts or cars all around the cutter.

The form of the knives appears also to be determined by experiments already made. All the facts point to the grooved knife as the one affording a chip best suited to diffusion. I have already pointed out in my previous reports the theoretical grounds which make a grooved knife desirable and the Ottawa experiments fully corroborated the predicates of theory. When smoothly cut chips fall into the diffusion cell the preponderance of contact is by the smooth surfaces. The moment the pressure of the current of diffusion is placed on this mass the proximate smooth surfaces of the chips are held so tightly together that the circulation of the liquid over them is entirely prevented. The result is the same as if the chips had been cut many times as thick. With a grooved knife such a packing of the chips is impossible and our experience has shown that with such chips and a battery of only ten cells the degree of extraction was greater than with a battery of fourteen cells or even sixteen cells using the smooth chips. It is true that a grooved knife presenting, as it does, a serrated edge to the canes will grow dull in much less time than a smooth knife would. The projecting parts of the edge strike the canes first and do most of the cutting. They will grow dull while the depressed portion of the edge still remains sharp. But with the arrangement for changing the knives which has been described, it makes little difference whether the knives be changed every few hours or only once every second day. Thus what a few years ago appeared to be the most difficult problem in respect of the application of diffusion to cane is now fully solved. The fear also that in cutting cane into such fine slices a loss of juice would occur has been proved to be entirely groundless. When the knives are left sharp and the speed of rotation is moderate there is absolutely no loss of juice from the cane. Thus in the experiments of only two or three years a cutter has been secured which, though by no means perfect, yet performs its work in a thoroughly satisfactory way. The form of the cutter having been chosen the next point is in respect of its position. In the arrangement of the apparatus at Almeria the cutter is placed on the ground.

At Djattiwangie the cutter, following the method used for beets, was placed above the center of the battery. The Java experimenters recognize the fault of this disposition and in the rearrangement of the machinery which is now going on the other position of the cutter will be chosen. The advantages of the ground plan are many. In the first place a cane-cutter, having harder work to do than a *coupe-racine*, must be made heavier. The erection of a stable foundation for such a weight of machinery is, of itself, a difficult and costly piece of work. The elevation of the canes to such a height is also a matter of considerable trouble. Even if the cane could be elevated as easily as the chips it would have to be twice handled, and this alone would be a serious objection to the elevated position of the cutter. The canes once elevated, the feeding the machine presents greater difficulties than if it were on the ground. The elevated cane is all delivered at one point. On the ground the canes can be delivered all around the cutter. It is therefore certain that in all future installations, made by engineers who have studied what has already been accomplished, the cutting machines will be placed with the surface of the cutting disk at the level of the ground.

THE DIFFUSION BATTERY.

Experiments already made have shown the form of cell suitable to the easy handling of cane chips. At Ottawa it was proved that a battery constructed on the plan of the ordinary apparatus used for beets was not capable of handling cane chips economically. These chips are moved with much more difficulty than the cossettes of beets. The latter are long and flexible, and flow easily through the discharge gates of whatever description. The rondelles of cane, on the other hand, are inflexible, moving only with great difficulty through a lateral or fundamental gate of the ordinary size. The cells of the Almeria battery have been constructed to meet this difficulty, and their action has been in every respect satisfactory. For the facile working of cane chips it is essential that the gate should be at the bottom of the cell and should have the same area as a horizontal section of the cell itself. The interior of the cell must be perfectly cylindrical. With this construction the charge of exhausted chips fall *d'un seul coup* directly the discharge gate is opened.

Having seen such cells in action, I cannot express too emphatically my conviction of their entire suitableness for working cane chips.

In respect of the form of the battery, the circular disposition is in every way preferable. Not only is such a battery more compact, requiring less space and smaller buildings, but the charging and discharging of it are much more easily accomplished than in a single or double line battery.

No device for charging diffusion cells has yet been invented which works as easily and economically as the pivoted gutter. Our experience at Ottawa showed that it was impossible to charge a line battery from

a belt conveyor as is done with beets. The friction of the cane chips on each other is so great as to prevent the automatic discharge of the chips through the lateral openings. Any method whatever of charging the cells from wagons is laborious and awkward, compared with the pivoted gutter. Since, as has been already mentioned, cane chips flow more difficultly than beet cuttings, the inclination of the gutter to the vertical should not be less than 45 degrees. The machinery for opening and closing the discharge gates should be so arranged as to be worked by workmen in charge of the battery, instead of being under the control of the workmen below, as is generally the case. The chief of diffusion has then under his control all the valves and cocks, on the proper manipulation of which the even and successful march of the process depends.

The closing of the discharge gate should be effected by the hydraulic rubber tube. This device is as simple as it is effective. By its use a perfectly tight joint is secured without any care on the part of the operator. The importance of such a joint is easily recognized by any one who has any practical knowledge of diffusion. It would be extremely difficult to make the joint tight with the ordinary rubber band which is used for the purpose. But with the hydraulic tube this is accomplished without any difficulty. It is only necessary that the pressure of the water within the tube be slightly greater than that of the liquid within the cell. This is secured by attaching the rubber tube to a small water tank about a meter above the one which supplies the cells or by connecting it directly with the water service which supplies the diffusion tanks. This pipe pouring the water into the tank from above, has always a slightly higher pressure than the pipes connected with the tank. The connection once made with the rubber tube, it remains unbroken during the entire manufacturing season. The joints of the upper door are made with a rubber gasket in the ordinary way. The cubical capacity of each cell should be for a battery to work 200 tons per day, about 20 hectoliters. When in good working order a cell is discharged every six or eight minutes.

NUMBER OF CELLS.

In respect of the number of cells of which the battery should be composed, I am not quite able to agree with the opinions of the European engineers. They affirm that a battery for cane should contain from two to four cells more than for beets, in order to secure the same degree of extraction of sugar. My own experiments have failed to discover anything in the histology of the cane, which indicates that it is more resisting to the osmotic force than the beet. On the contrary its composition reveals a cellular structure, which appears to be more susceptible to osmose. It is true that an increase in the number of cells increases the time the chips are undergoing diffusion, and theoretically the density of the withdrawn juice, and the degree of the extraction of

the sugar. But after the tenth cell, this progress is so exceedingly slow that I doubt whether there is any economy in carrying it on.

With a battery of twelve cells ten are always under pressure. If a diffusion is made every six minutes, the time during which the contents of each cell is undergoing osmose is one hour. With a battery of sixteen cells this time would be increased to eighty-four minutes. I do not doubt but that a benefit would be derived from this prolongation of the diffusion process, but I doubt whether this benefit would be proportionate to increased expense of the plant.

It must be remembered, however, that the working of a battery of sixteen cells could be as economically performed as with a smaller number. I have no word of discouragement, therefore, for those who would prefer the battery with the larger number of cells. Furthermore, if the cutter gives a smooth chip, then I would most strongly recommend the larger number. In my opinion the work of a battery of sixteen cells with smooth chips would be no more effective than one of twelve cells with chips properly grooved. In the erection of a circular battery of twelve or fourteen cells it is always advisable to place them so that two or four additional cells may be added without disturbing the valves or connections of the parts already erected. The difference in cost between a twelve and sixteen cell battery is about $4,000, the cost of each cell with all its appurtenances being about $1,000.

The battery should be placed high enough from the ground to permit a dump cart to be driven under the cells to receive the exhausted chips. This arrangement saves the expense of a chip elevator and can be easily adopted. The carts can then remove at once the chips to the field or bagasse yard, where they can be placed in heaps and allowed to partially decay before being used for manure. The usual method of emptying a cell is to allow the last charge of water to flow out with the chips. This not only causes a considerable waste of water, but also a little sugar is always found in this waste. It would be a source of inconvenience also, if the arrangement for receiving the chips just mentioned is adopted, to allow this mass of water to fall on the carts and upon the roadway over which the wagons pass. The apparatus for using compressed air, on the contrary, is not of so much importance where water is abundant, and when the chips fall into a pit to be taken by an elevator to the carts. In such circumstances the use of compressed air may become of little utility. The installation of this apparatus is somewhat expensive and could therefore be omitted on the score of economy.

With a battery and cutters constructed on the principles described the loss of sugar in the chips will not be more than .25 per cent. The weight of juice obtained will be about 10 per cent. greater than that of the cane used. In case all the juice could be expressed from the cane its weight would amount to 90 per cent. of the cane subjected to pressure. Thus for equal amounts of sugar in mill and diffusion juice the

quantity of water to be evaporated will be as 90 to 110. The force required for the evaporation of diffusion juice for a given quantity of sugar made will therefore be 22.5 per cent. more than for mill juice. On the other hand, for a given quantity of cane the fuel required for slicing it will be to that required for crushing it as 10 to 100; and an equal amount for the calorisators and driving the elevators, &c., and the total consumption of fuel for a given quantity of cane, is as 20 to 100. But from this quantity of cane by diffusion at least 10 per cent. more sugar can be made than with the best mills. Thus the consumption of fuel for the extraction of a given quantity of sugar from cane is not much over one-quarter as great by diffusion as by mill. It appears from the most careful consideration of the data at hand that the total consumption of fuel for a given quantity of cane is about the same for the two processes. Whatever excess of sugar, therefore, can be produced by diffusion will be a clear profit to the manufacturer. It is not extravagant to say that this increase will not be less than 10 per cent. It is almost impossible for any accident to happen to a properly constructed diffusion apparatus. This is no small matter when we take into consideration how often accidents, and these too of a serious nature, happen to cane mills. The vexation, worry, and expense of such accidents will be entirely avoided by the introduction of diffusion.

The disposition to be made of the chip-bagasse is still a question for experiment and discussion. As it issues from the diffusers it contains not less than 88 per cent. of water; *i. e.*, the chips contain a weight of water approximately equal to the weight of sugar and water combined in the cane. The task of drying this material by any artificial means is one of extreme difficulty. When passed through a press such as is used with beet pulp the content with water is reduced only about 10 per cent. To pass it through rolls which would make it as dry as mill bagasse, a degree of pressure and an amount of power must be used almost as great as would be required to crush the cane at once with rolls. In order to burn well in a properly constructed bagasse furnace the chips must not contain more than 45 per cent. of water. To burn in an ordinary furnace this must be reduced to 25 per cent. At the present time I will say that there is no prospect of being able to use this material as a fuel outside of those countries where the sun can be relied on to do all the drying.

In Egypt and Spain, and some seasons in Java, the sun-light is constant and effective. But in Louisiana it would be idle to attempt to dry the chips in this manner. But two uses for them remain to be considered. They can be used for paper pulp or as the basis of a fertilizer. The chips are in an excellent state for treatment for paper pulp, and, as has already been found, make a good paper. In the soil their mechanical effect will be beneficial, especially in all heavy soils or in fine and closely packed alluvium. Decaying they will yield also a small quantity of chemical fertilizer. Placed in heaps and treated as

at Torre del Mar, with the waste waters of a distillery, they form the basis of an excellent manure. The inability to use the chip-bagasse as a fuel, in my opinion, is the only tenable objection to the general introduction of diffusion. I do not seek in any way to conceal the magnitude of the difficulty, but believe that a candid consideration of the problem will show that diffusion is desirable, even when full force is allowed to this objection against it.

TREATMENT OF DIFFUSION JUICE.

The juice issuing from the diffusers differs in many important respects from mill juice. Experience has shown that it is no purer than mill juice; *i. e.*, that the ratio of sucrose to other substances is no higher. But the impurities are of a somewhat different nature. The process of diffusion tends to bring into the juice all the gum, soluble starch, &c., that is contained anywhere in the cane, but at the high temperature at which it is now conceded the diffusion should take place much of the albuminous matter is coagulated and retained in the chips. From this it happens that in the ordinary process of defecation there is not enough coagulum formed to entangle and bring to the surface any notable proportion of other impurities. This point is intensified by the greater dilution of the diffusion juice. Hence, while with the ordinary processes of defecation, diffusion juice may be prepared for concentration the thoroughness of the purification is much less than with mill juice and far below the requirements of a first-class product. For this reason I fear that if the ordinary methods were our only resource, the hope of a general introduction of diffusion would be vain.

But the case is far different when a large excess of lime, from 1 to 2.5 per cent., according to the quality of the juice, is added to the liquid and afterwards the excess of lime precipitated by carbonic acid. This process, known in France as *carbonatation*, and in Germany as *saturation*, produces a most happy effect. Not only are the albuminous bodies largely removed, but all the other impurities which cause the juice to look muddy are carried down with the precipitate of carbonate of lime which is formed. This precipitate is granular and can be easily separated from the juice by the filter press. The process of carbonatation cannot be continued until the whole of the lime is removed without danger of setting free again some of the impurities in the juice. When this happens a scum is formed on the surface which has the same characteristics as that formed by the ordinary process of defecation. For this reason the treatment of the mass with carbonic acid is stopped when the content of lime is reduced to about two-tenths of a gram per liter. If now the whole be sent to the filter press the coagulated impurities and precipitated lime are gathered in the chambers of the press in firm, hard cakes, and the juice issues perfectly clear and transparent.

At this point the experiments of the Department have shown the fur-

ther treatment of cane juice differs materially from that of beet. Indeed the first part of the process is materially different. In beet juices, which contain no glucose, the carbonatation is carried to a high temperature while with cane juices, containing as they do a large percentage of glucose, the process must be conducted at as low a temperature as possible to avoid the destructive action of the lime on the reducing sugar. With beet juices the process just described is repeated, only less time is used for the second carbonatation than with the first. If the manufacturer does not want to save his molasses, the same process can be followed with cane juices, and that was actually done at Almeria and Djattiwangie. But a better process is to send the filtered juice from the first carbonatation to pans where it is saturated with sulphurous acid. This saturation has a double purpose. First, it removes the remaining portion of the lime, and next it discharges the coloring matters which the juice contains. From these pans the juice passes again through the filter press (a little different construction from the first set) and issuing thence is ready for the triple effect pan. The best forms of machinery for these several operations I believe will be found in the plans which have been given in this report, plans which have been prepared by the best sugar engineers in Europe, after I had laid before them, what, in my opinion, should be the variations from the common forms of machinery used in the manufacture of beet sugar. Believing as I do that with a proper application of sulphurous acid to carbonatated sugar juices the use of bone-black in the manufacture of the first-class coffee and table sugar may be omitted, I have endeavored to present in the drawings and estimates which have been given the very best forms of sulphurizing apparatus that can be described. I believe the specifications of this part of the apparatus will meet with the approbation of every competent sugar-maker who will take the trouble to study them. From actual trials of the methods of defecation herein set forth and from a careful study of somewhat similar methods which have been tried in other countries I can confidently say to the sugar-growers of the country that they are the simplest, cheapest, and best methods of purifying cane juices known to the science or art of sugar-making. One most important advantage possessed by these methods is in the saving of sugar which they secure. As has long been known and as set forth by an analytical study in Bulletin No. 5, the waste of sugar in the scums and sediments by the common method is very great. I am not prepared to adopt the, to me, somewhat extravagant views of some manufacturers who place this loss at 15 per cent. of the total sugar entering the clarifier, but there is no doubt of its being very great. By carbonatation and saturation with sulphurous acid this loss is entirely avoided. By a careful desucration of the filter press cakes the loss is reduced to a minimum and in no case will it amount to a great deal. The press cakes make an excellent fertilizer. In many parts of the country where sugar is grown limestone is not abundant. In such cases the difficulty

and expense of obtaining limestone may be an objection to the process of carbonatation. But this objection fails when it is remembered that the cost of getting the limestone will not be much greater than that of buying lime for the common process of defecation. For a crop of 10,000 tons of cane, 700 tons of limestone will be sufficient and the value of the press cakes and lime waste as fertilizers will more than pay the cost of the stone.

The further treatment of the purified juices is not a subject which has been discussed in this report. I will say in passing that no sugar factory which is abreast with modern science and modern progress will boil sugar juices, in preparing them for the strike pan, in open pans. The loss of sugar by such a process is great, but the waste of fuel is a matter of far greater concern. A triple or at least a double effect is as necessary to the equipment of a sugar factory as a breech-loading rifle is to that of a soldier. The manufacturer who boils thin liquor in an open pan is as far behind the times as the soldier who enters battle with a muzzle-loading flint-lock musket. The Welner-Jelinek triple effect, first described in Bulletin No. 5, has lately been improved by its maker, the Hallesche Maschinenfabrik, and is now, in my opinion, the very best evaporating apparatus in use.

The juice of cane obtained by diffusion being so much more dilute than mill juice, needs a triple effect for its proper treatment as much as it needs double saturation.

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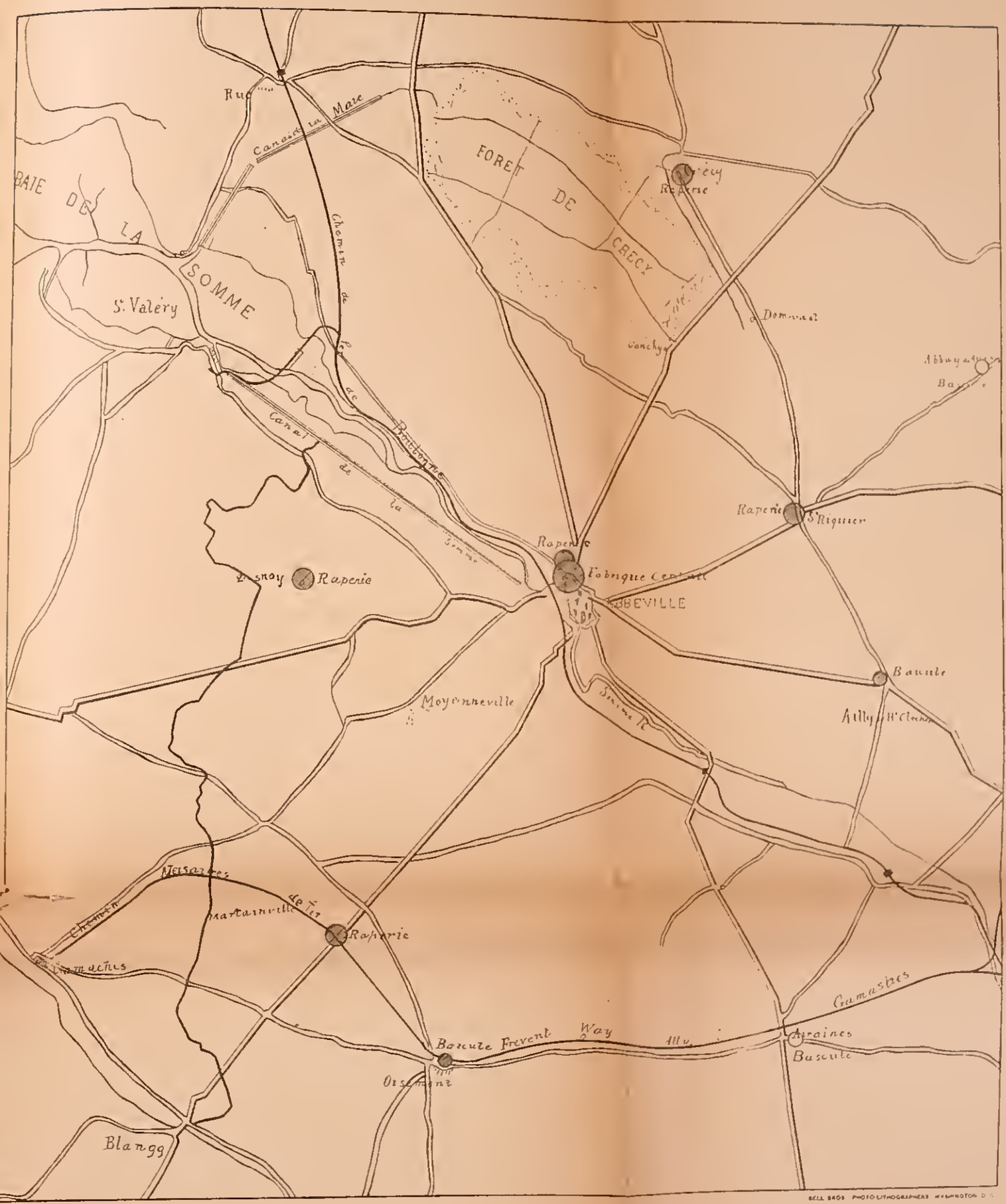
BAIE

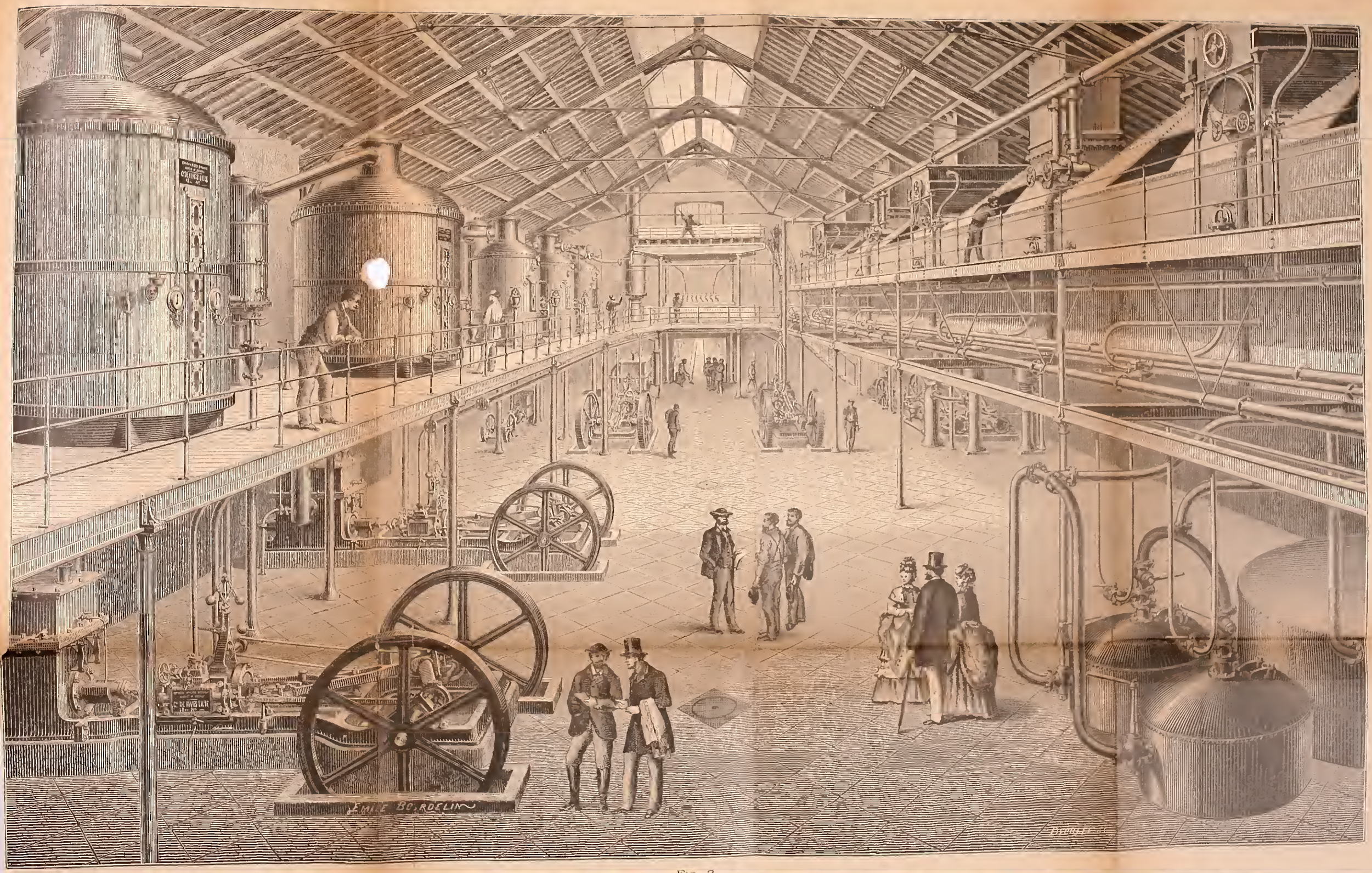
Sugar Factory of Abbeville

Sucrerie d'Abbeville

Fig. 1.

Positions of the Refineries and bascules
Emplacements des raperies et bascules





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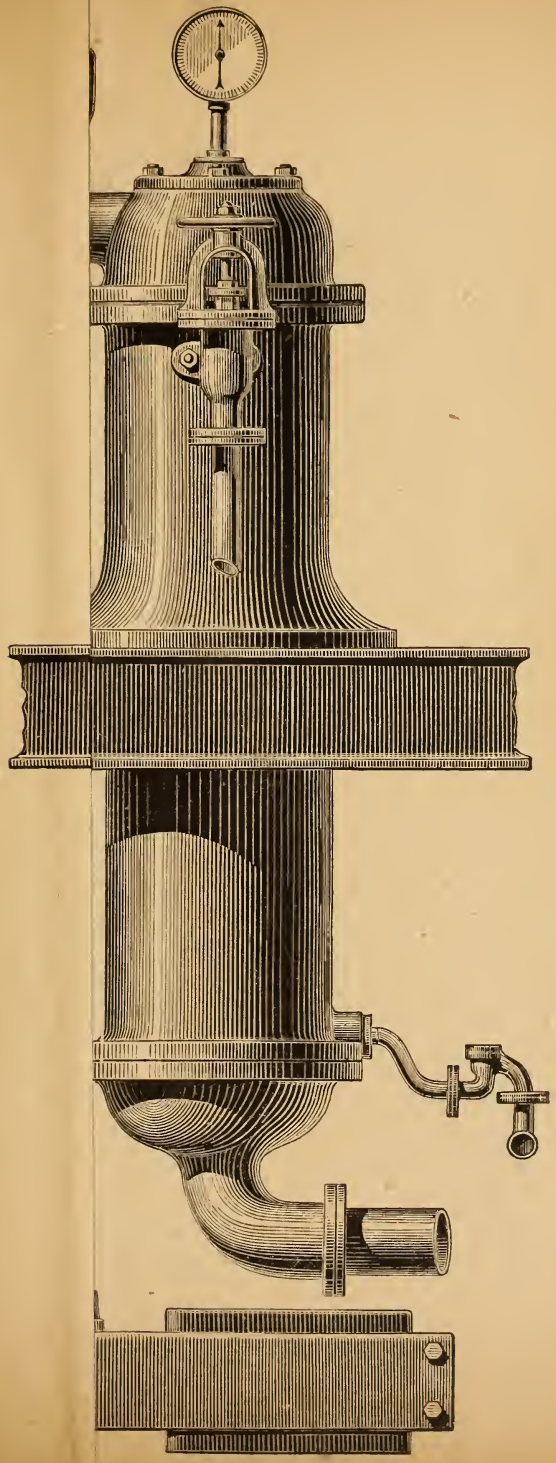
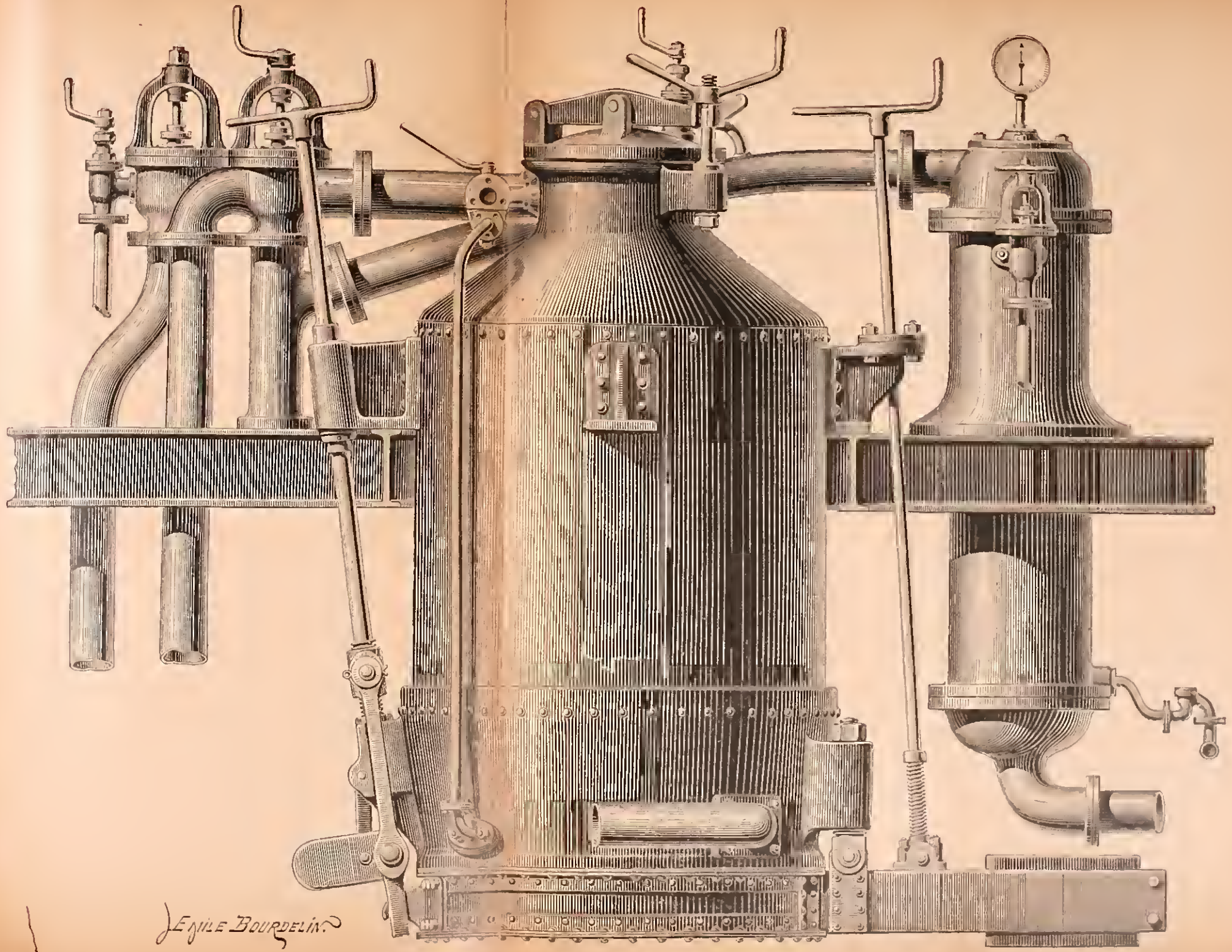
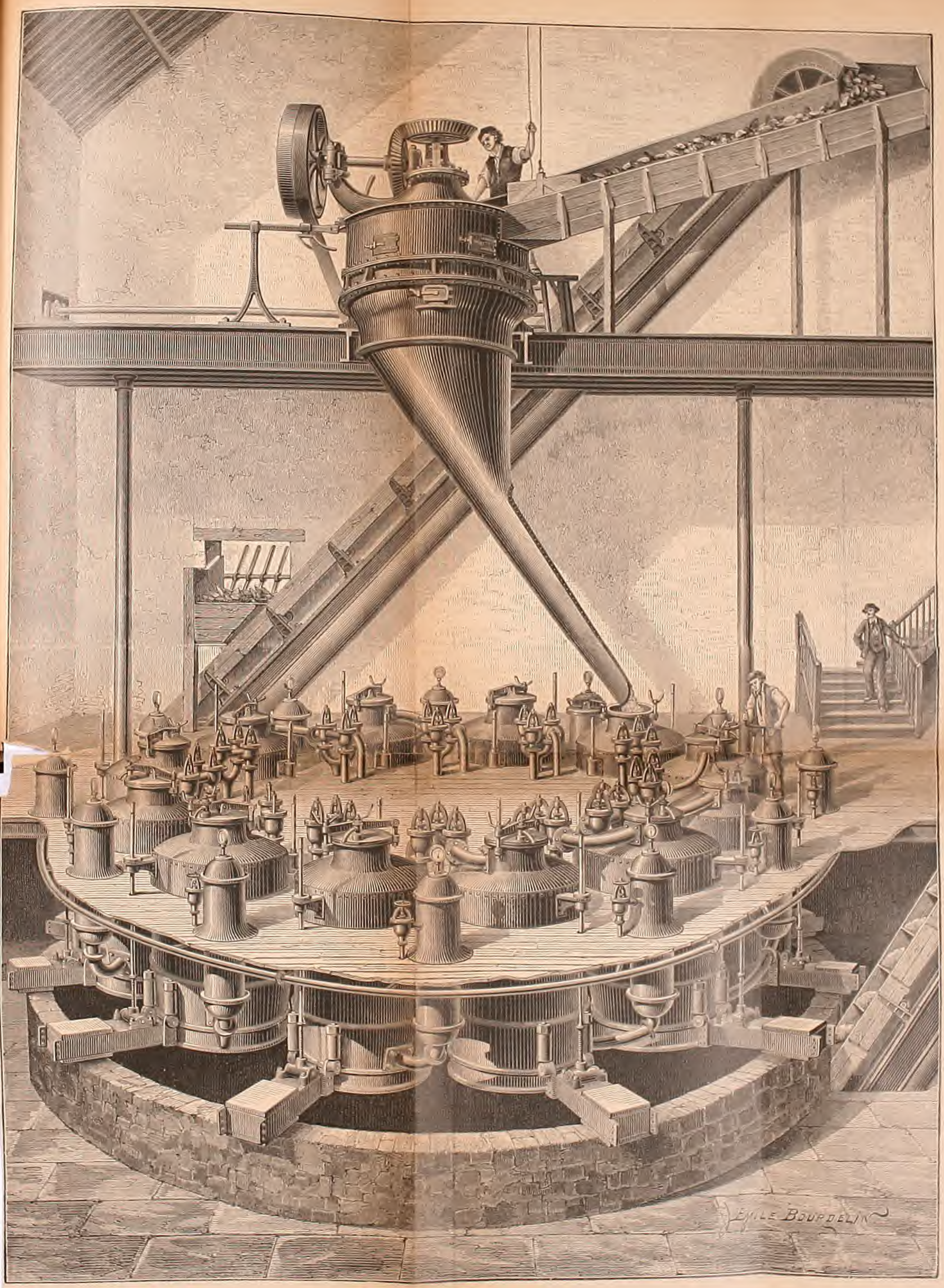




J. Emile Bourdelin.

Fig. 3.



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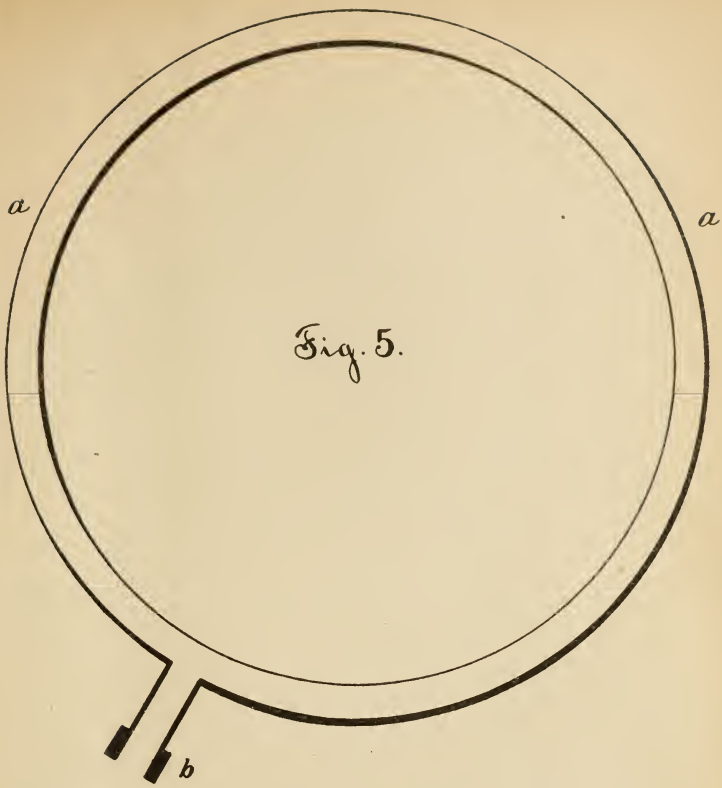

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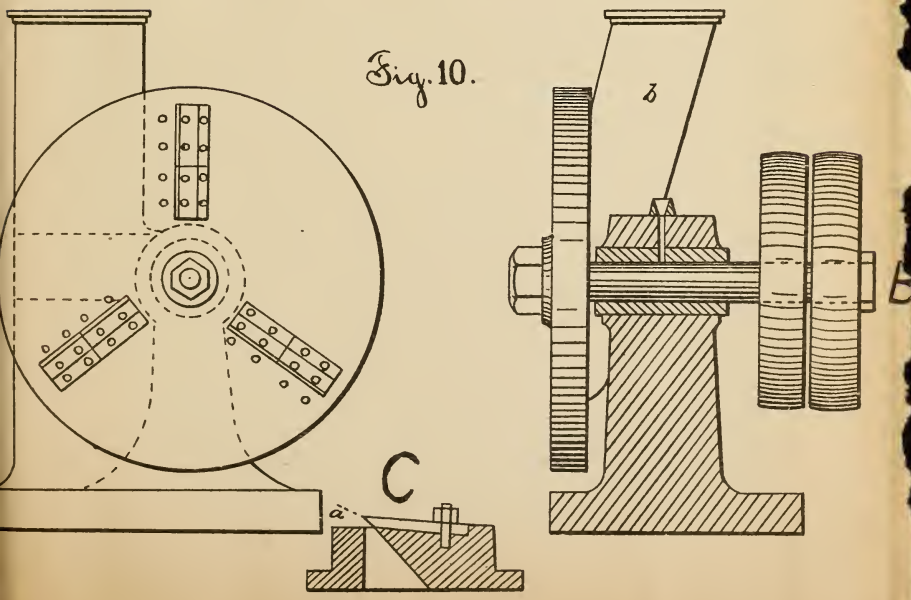

Fig. 10.

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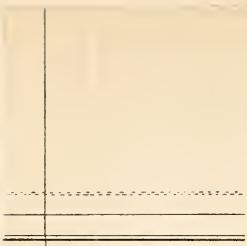

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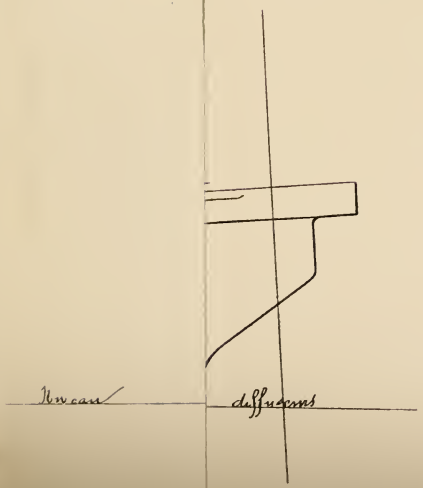


Appareil de diffusion

Travaillant 200.000 Kgs de cannes en 24 heures

Ensemble du diffuseur

Fig 6.

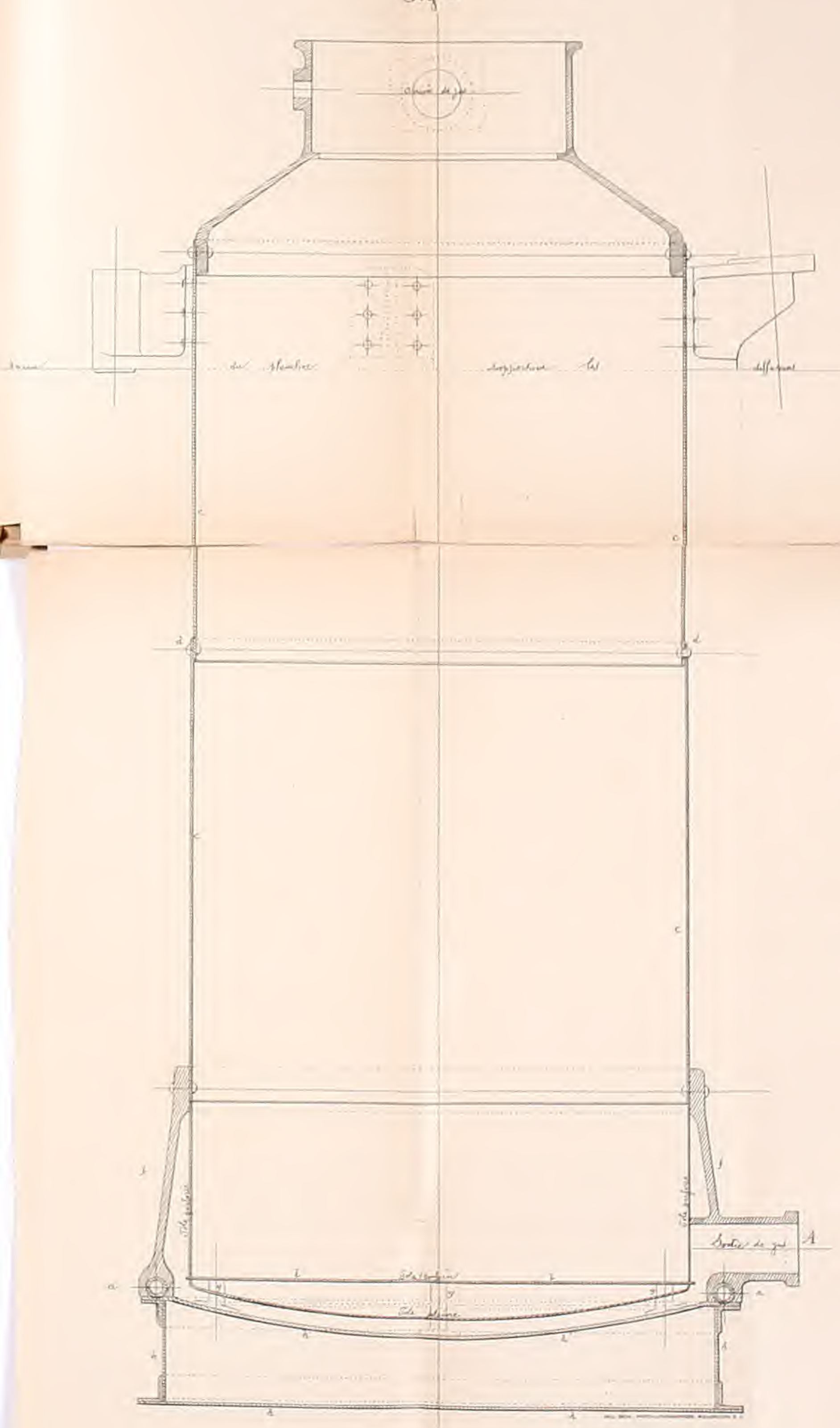
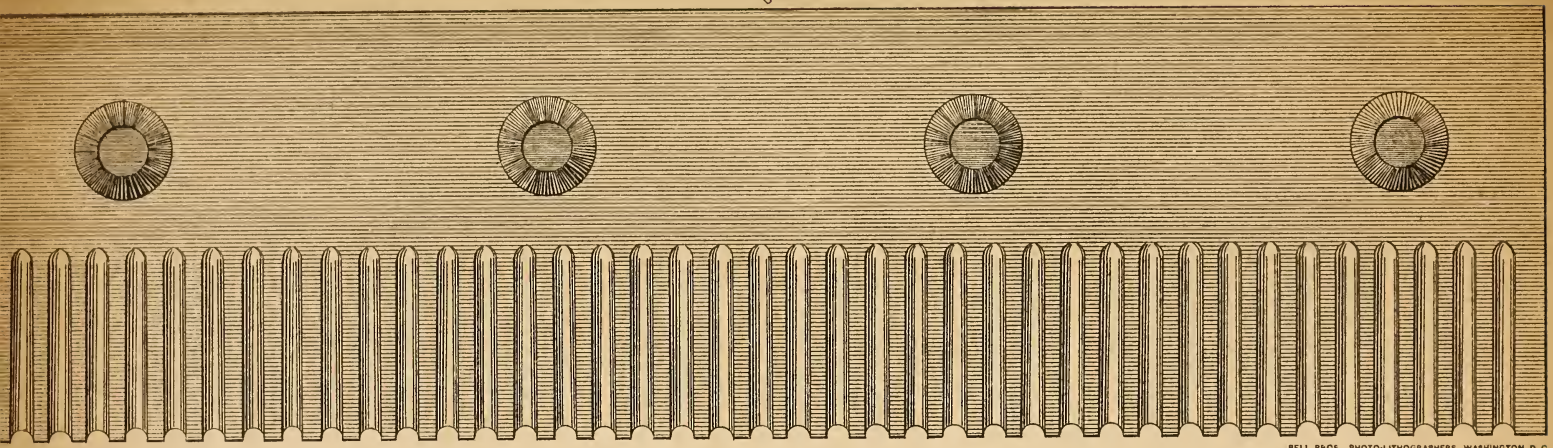


Fig. 7.



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Cutting Knife of the Pusey & Jones Co.

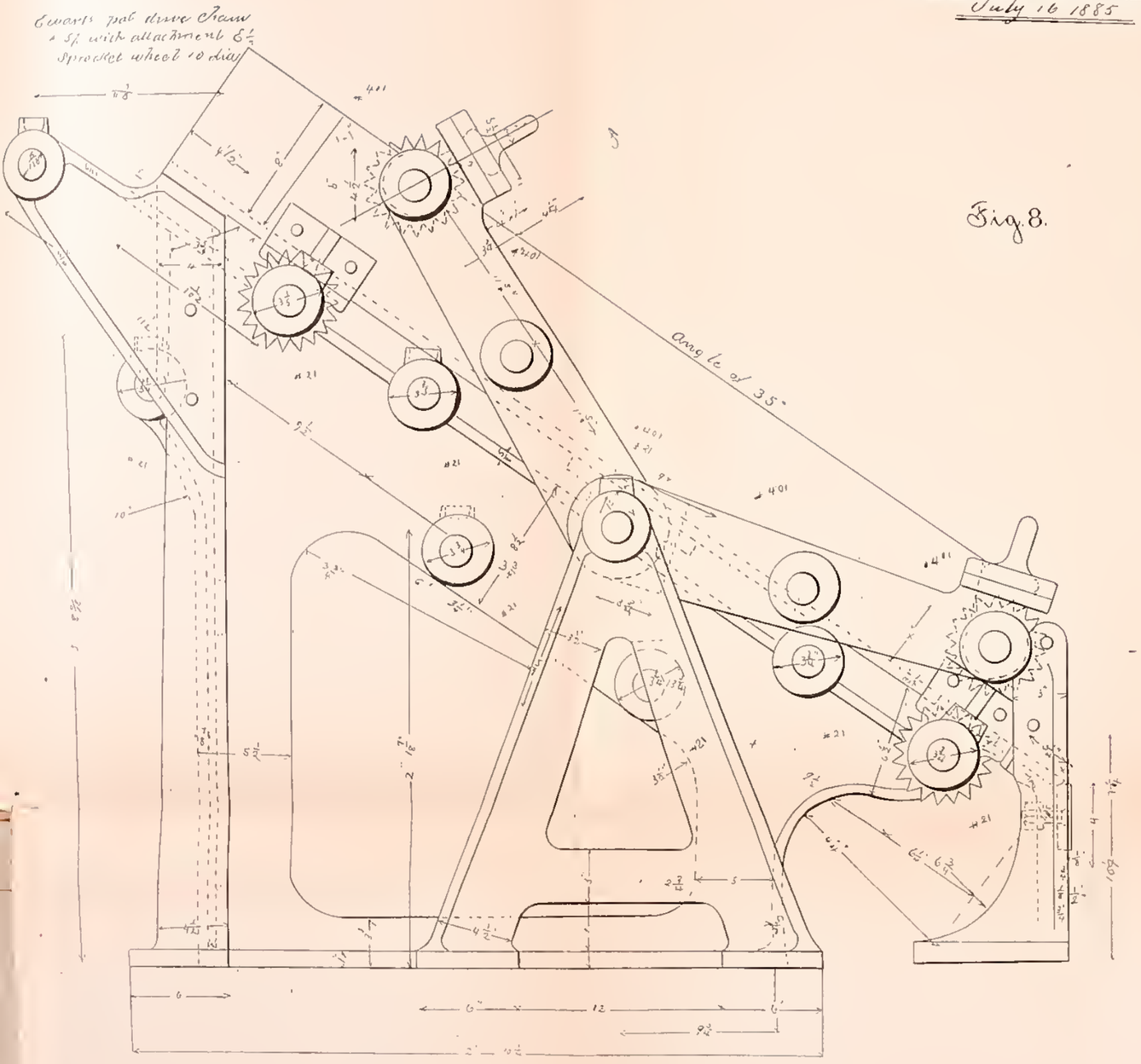
Details of Sugar Cane Cutter

THE PUSEY & JONES COMPANY

WILMINGTON DELAWARE

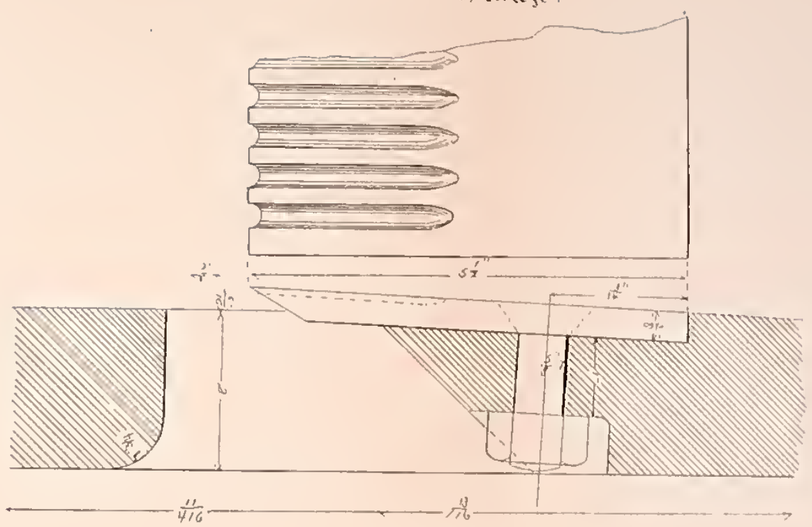
July 16 1885

Fig. 8.

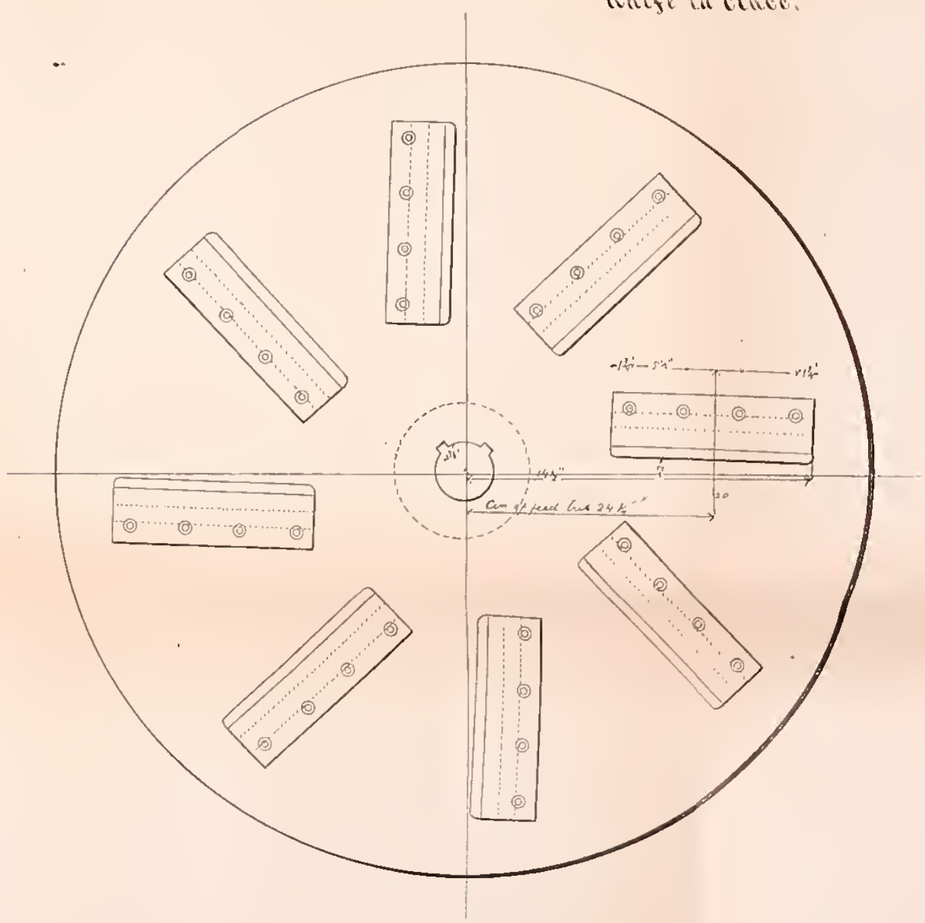


Forced Feed.

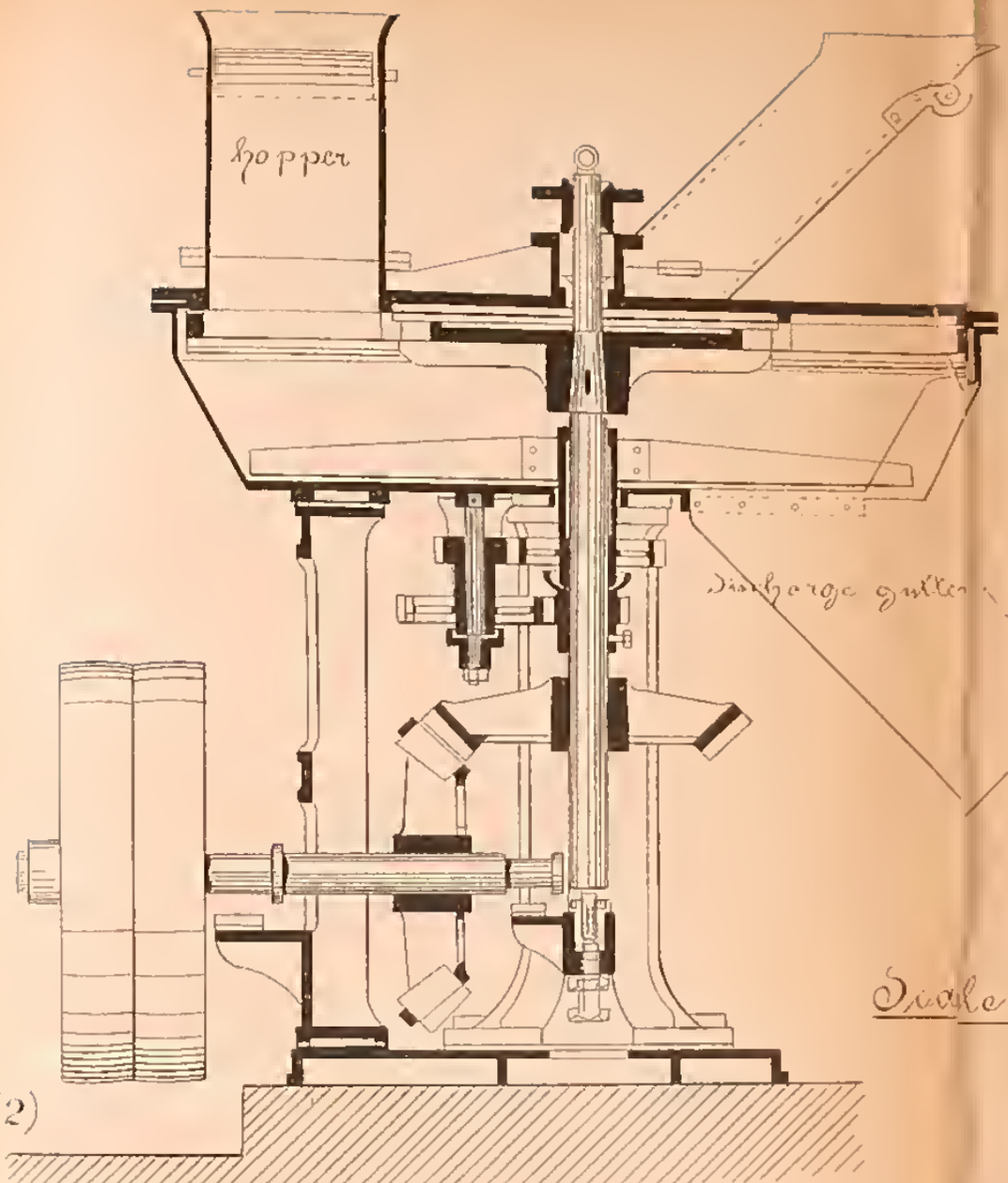
Plan of Knife.



Knife in Place.



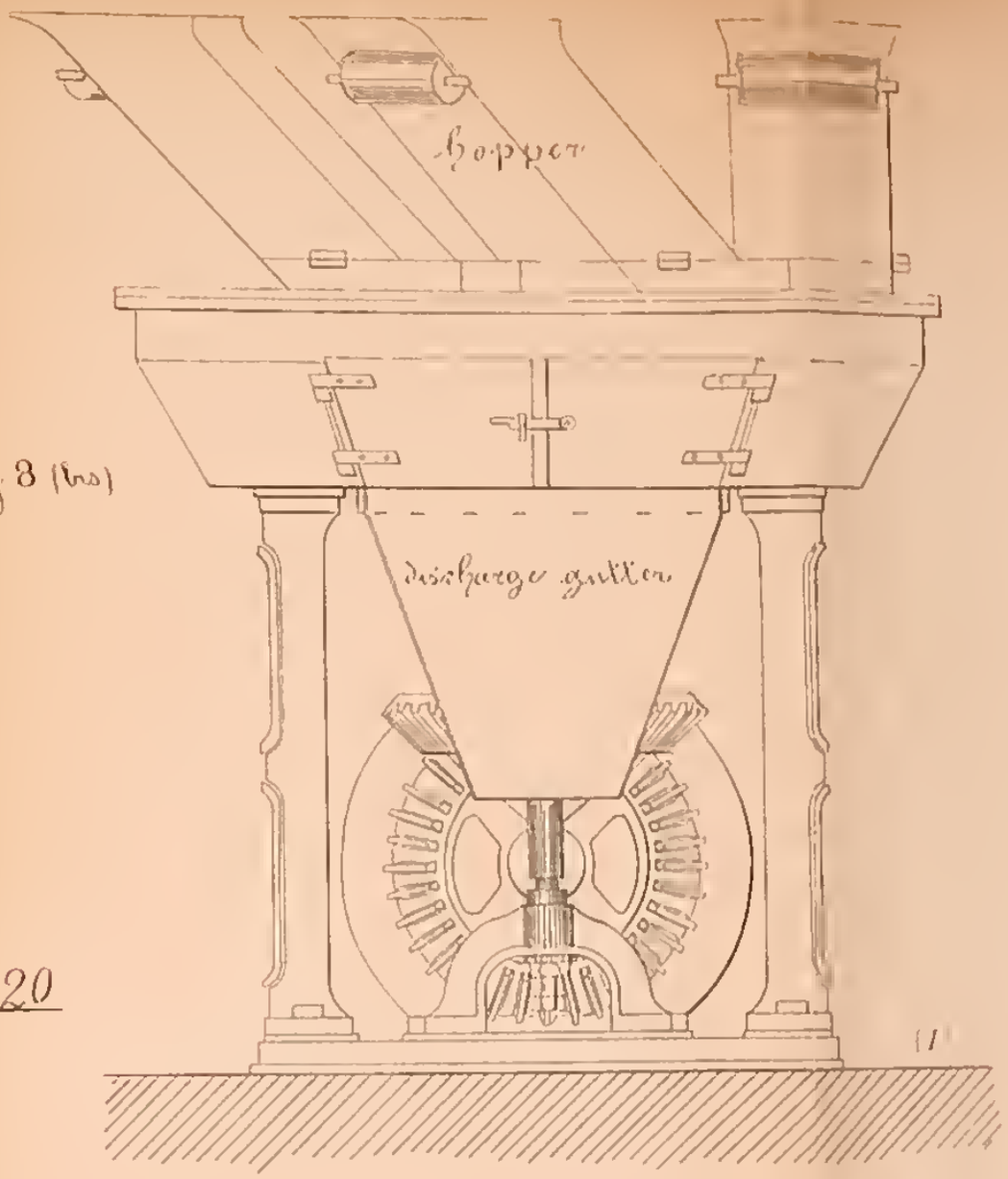
Cutting Disc.



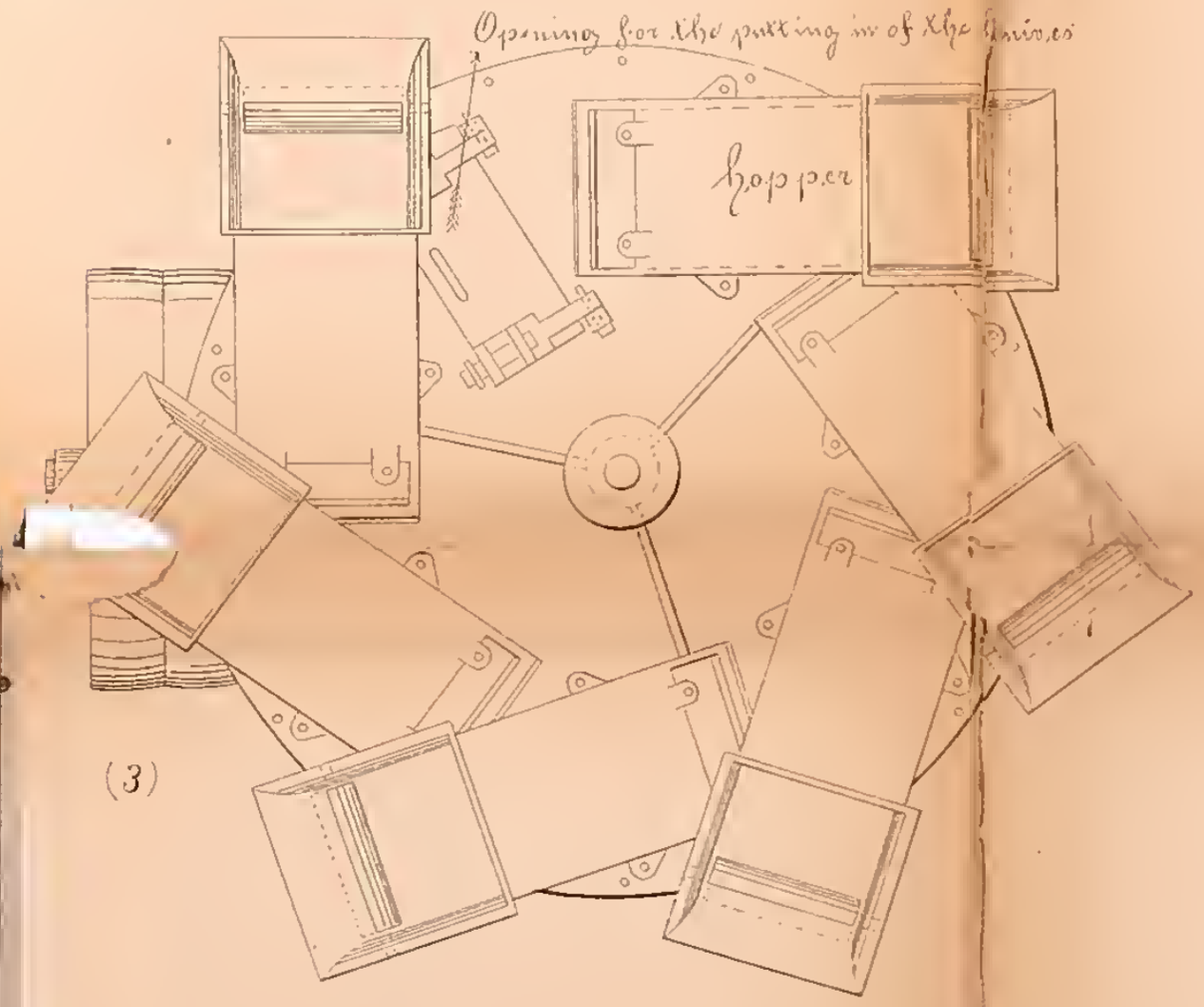
(2)

Fig 8 (bis)

Scale 1:20



(1)



(3)

Cane slicing machine.

system of the

Sangerhäuser Actien-Maschinenfabrik

& Eisengiesserei.

Sangerhausen. Germany.

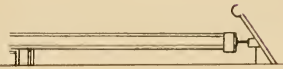
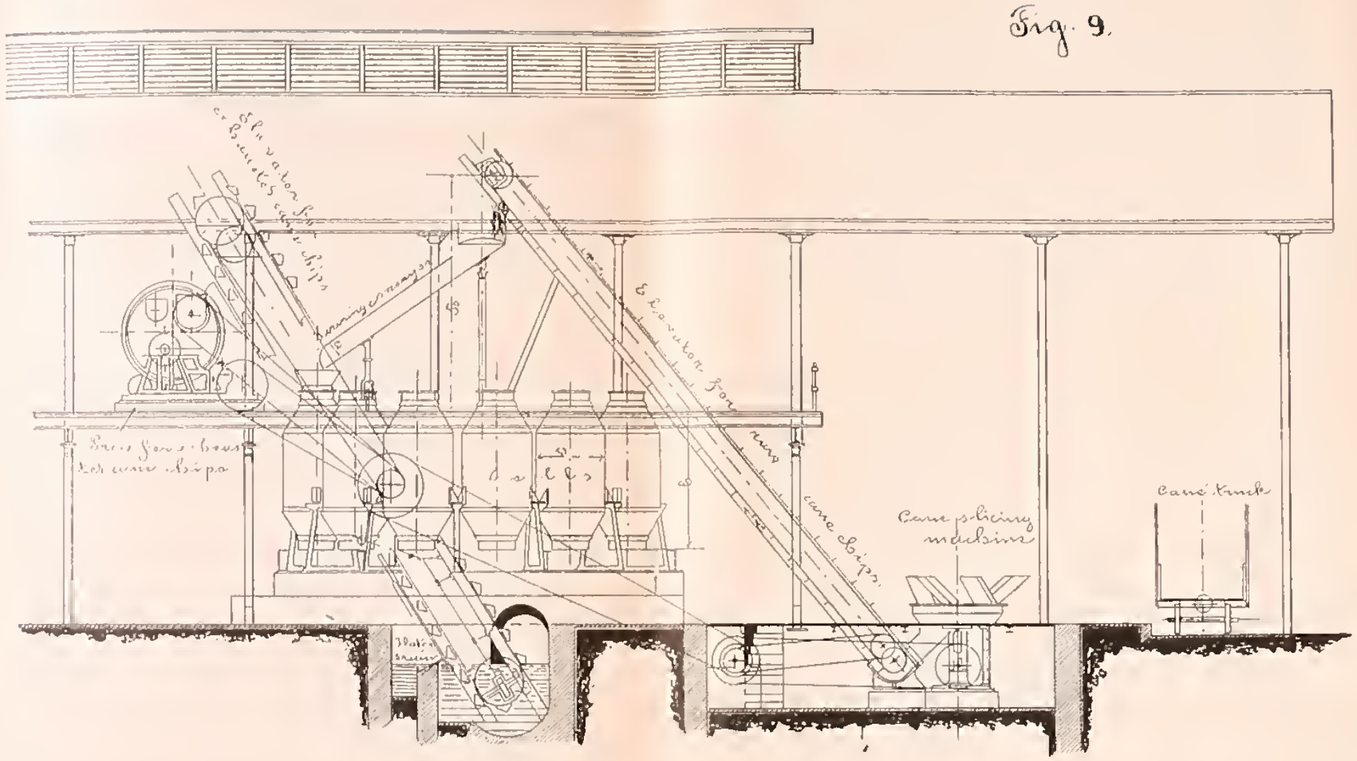
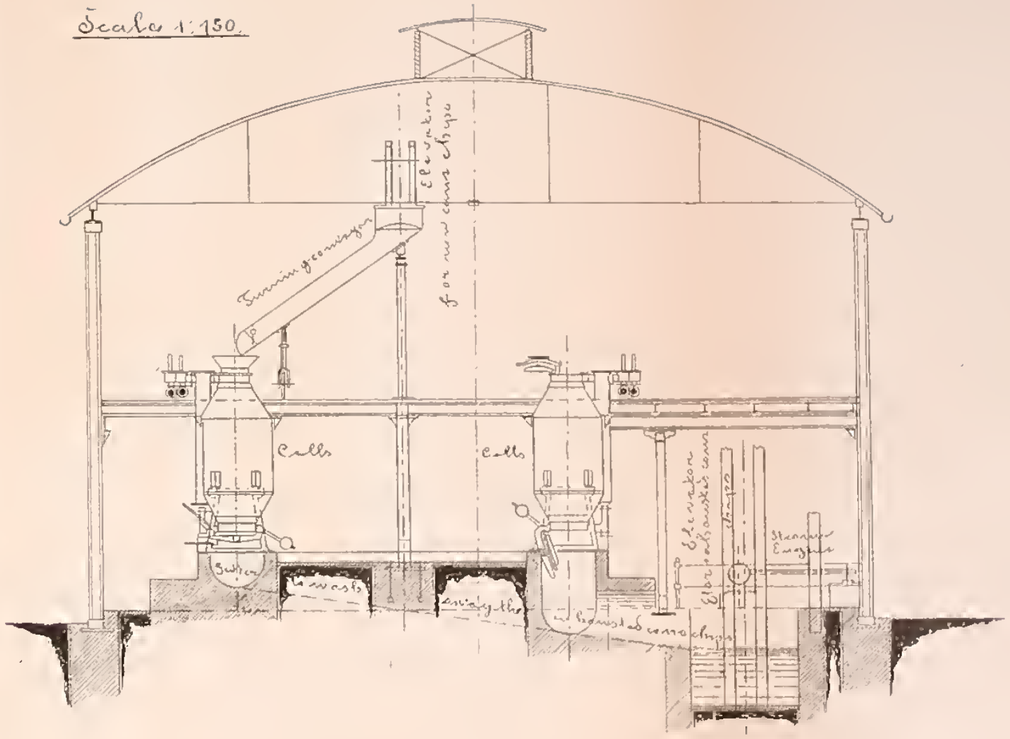
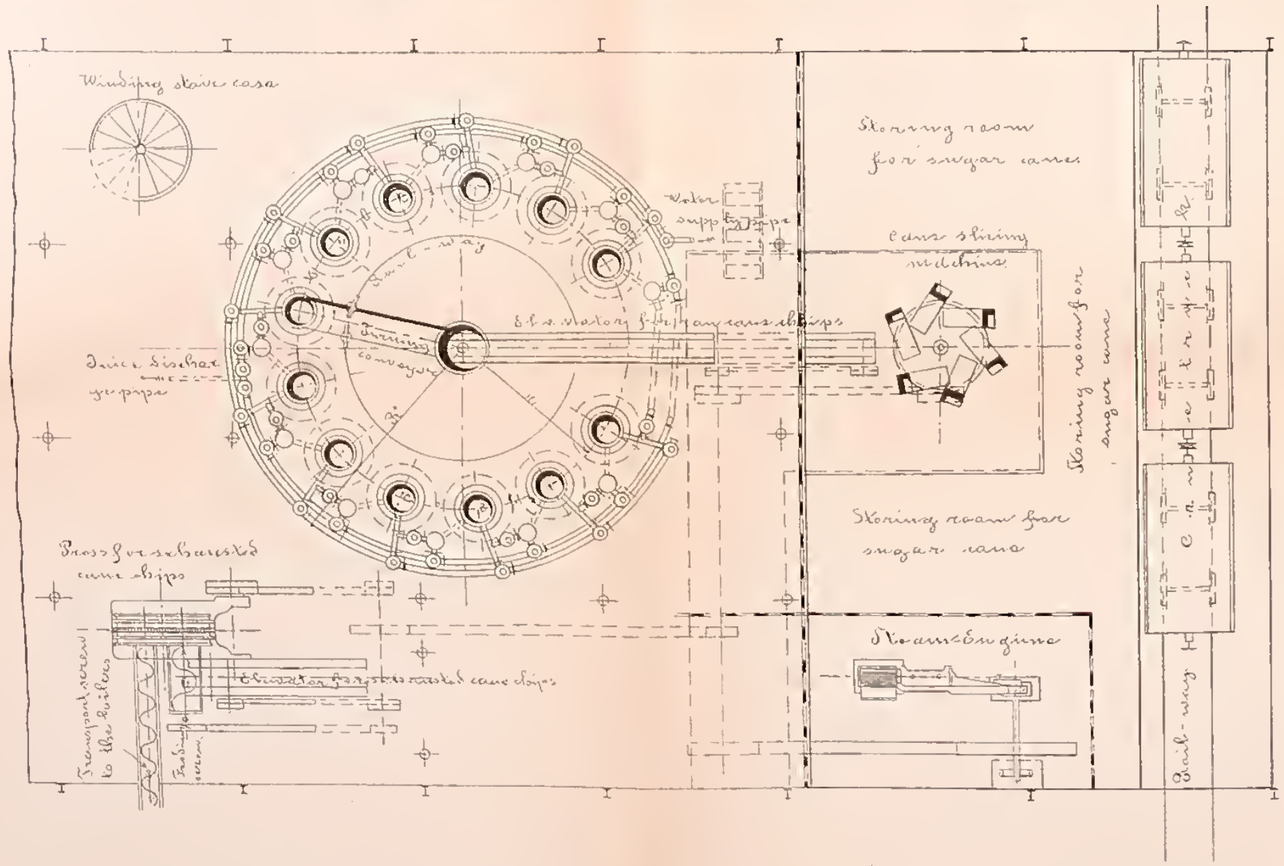


Fig. 9.

Scale 1:150.







Slawofsa

Diffusion Plant for sugar cane

system

Sangerhäuser Aktien-Maschinenfabrik

u Eisengiesserei.

Sangerhausen. Germany.

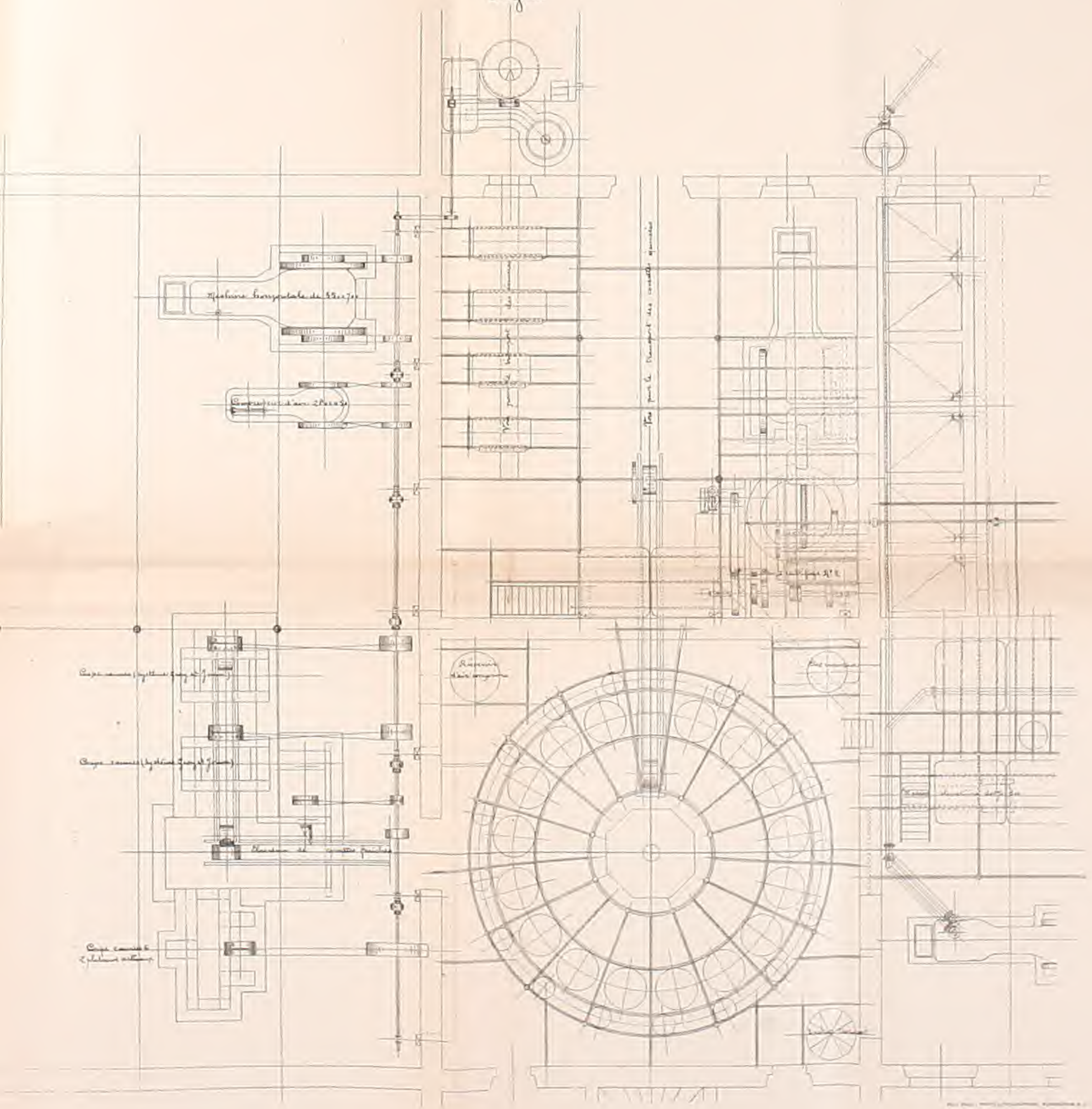
Sucrerie de cannes d'Almeria (Espagne.)

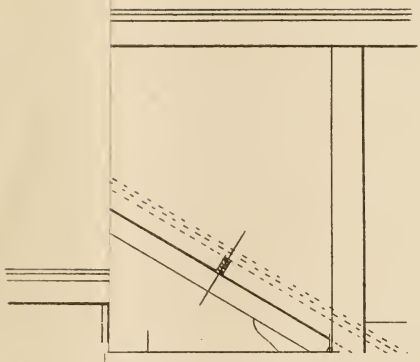
Installation des appareils pour la diffusion.

Vue en plan.

Echelle de 1/50

Fig. 11.





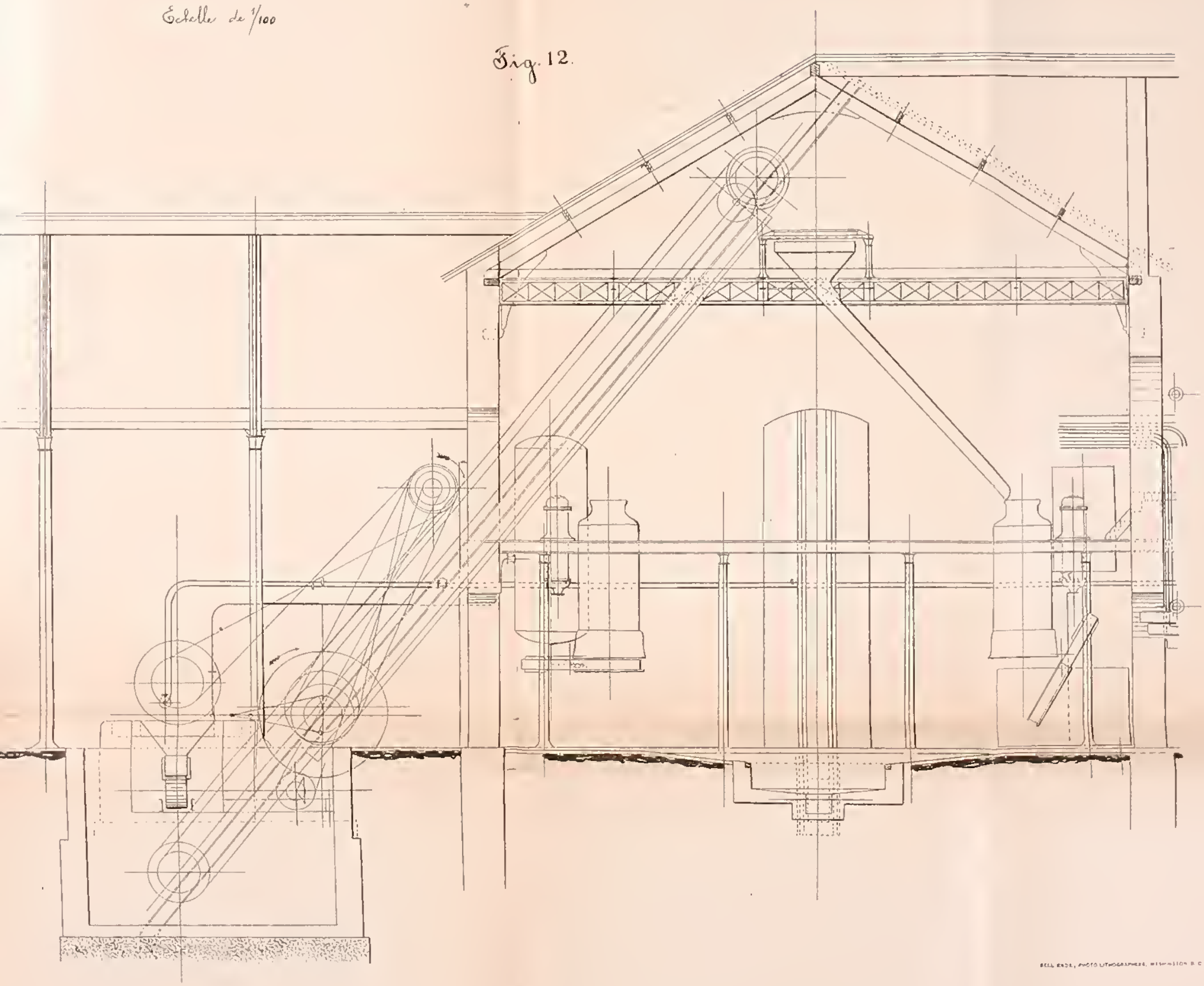
Sucrerie de cannes d'Almeria (Espagne.)

Installation des appareils p.r la diffusion.

Coupe longitudinale.

Echelle de 1/100

Fig. 12.

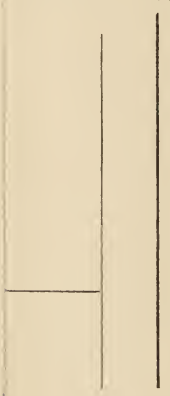


BELL BROS., PHOTO LITHOGRAPHERS, WASHINGTON D.C.

lar (Esp

e 10xissusent

Echelle au 1/75



Sucrerie de cannes de Vorre del Mar (Espagne)

Installation d'une Batterie de 10 diffuseurs

Vue en plan

Le 28 Décembre 1885

Echelle — 1/15

Fig. 13.

Chemin de roulement de la voiture
Road for carrying the charging wagon

Wagon to charge Diffusers

Elevateur de caisses
Elevator of the Chips

PHOTO LITHOGRAPHERS, WASHINGTON, D.C.

pagne.)

ur.

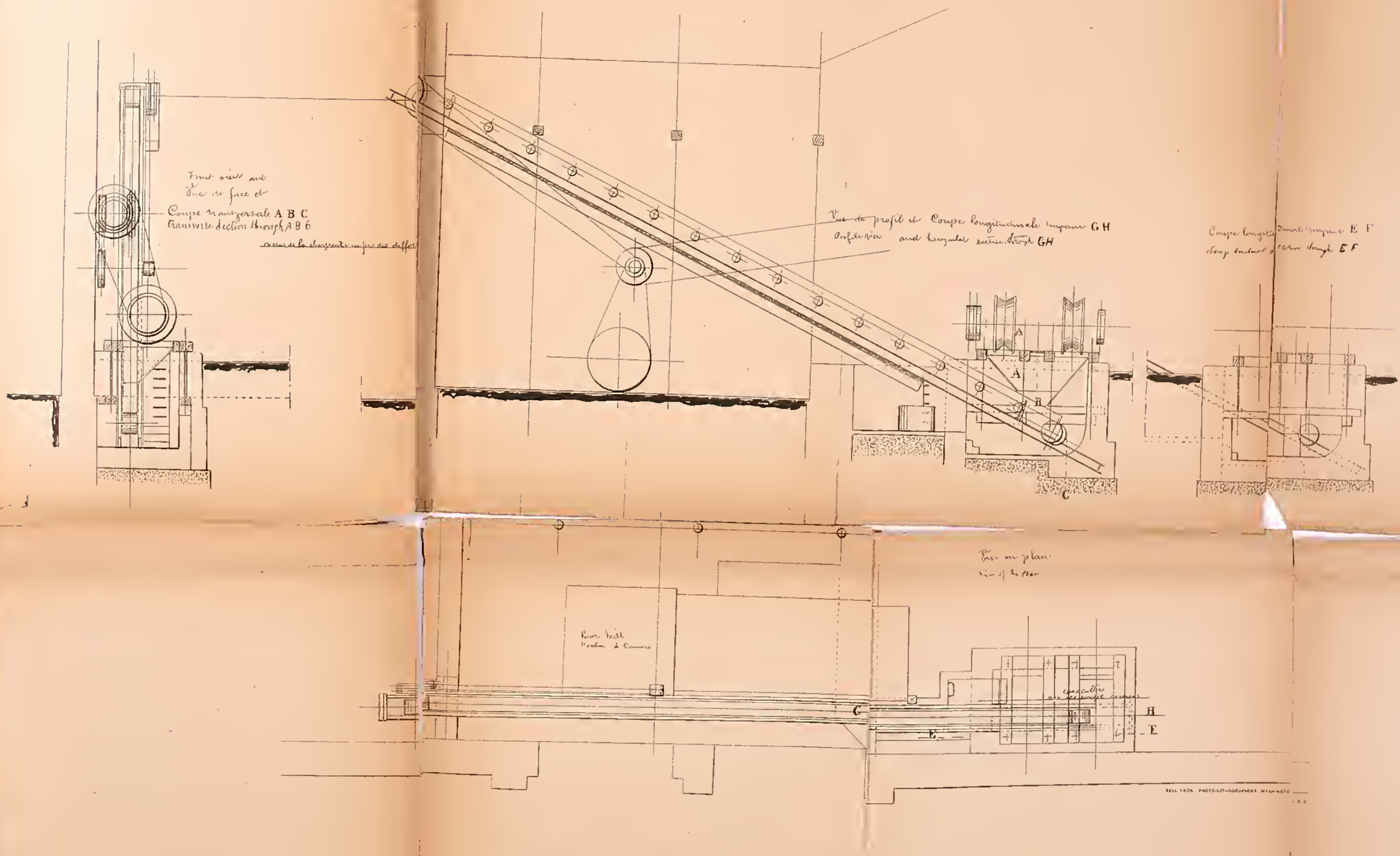
Sucrerie de cannes de "Torre del Mar" (Espagne.)

à M. M. Larios Freres.

Installation des coupe-cannes et de l'élévateur.

Echelle de 1/100

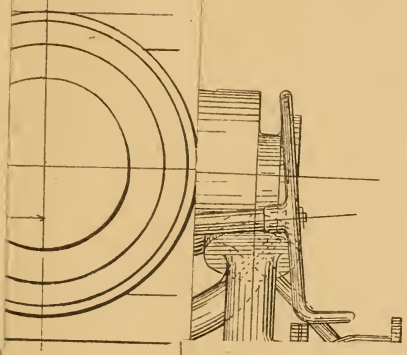
Fig. 14.



del - M o

diffuseu

metres/



Sucrerie de Cannes de Torre-del-Mar (Espagne.)

Installation des diffuseurs

(Lengths in millimetres)

Fig. 16.

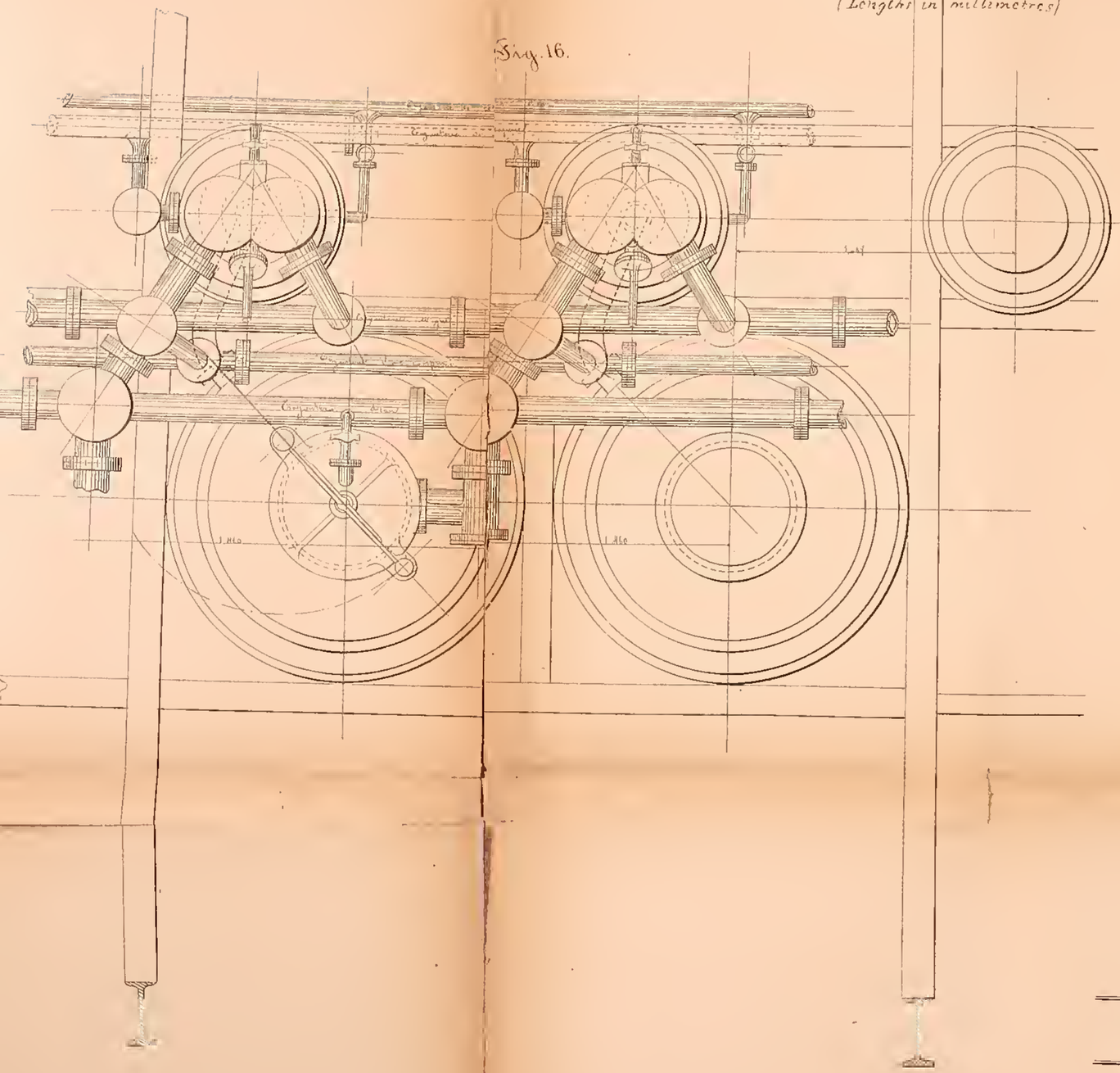


Fig. 15.

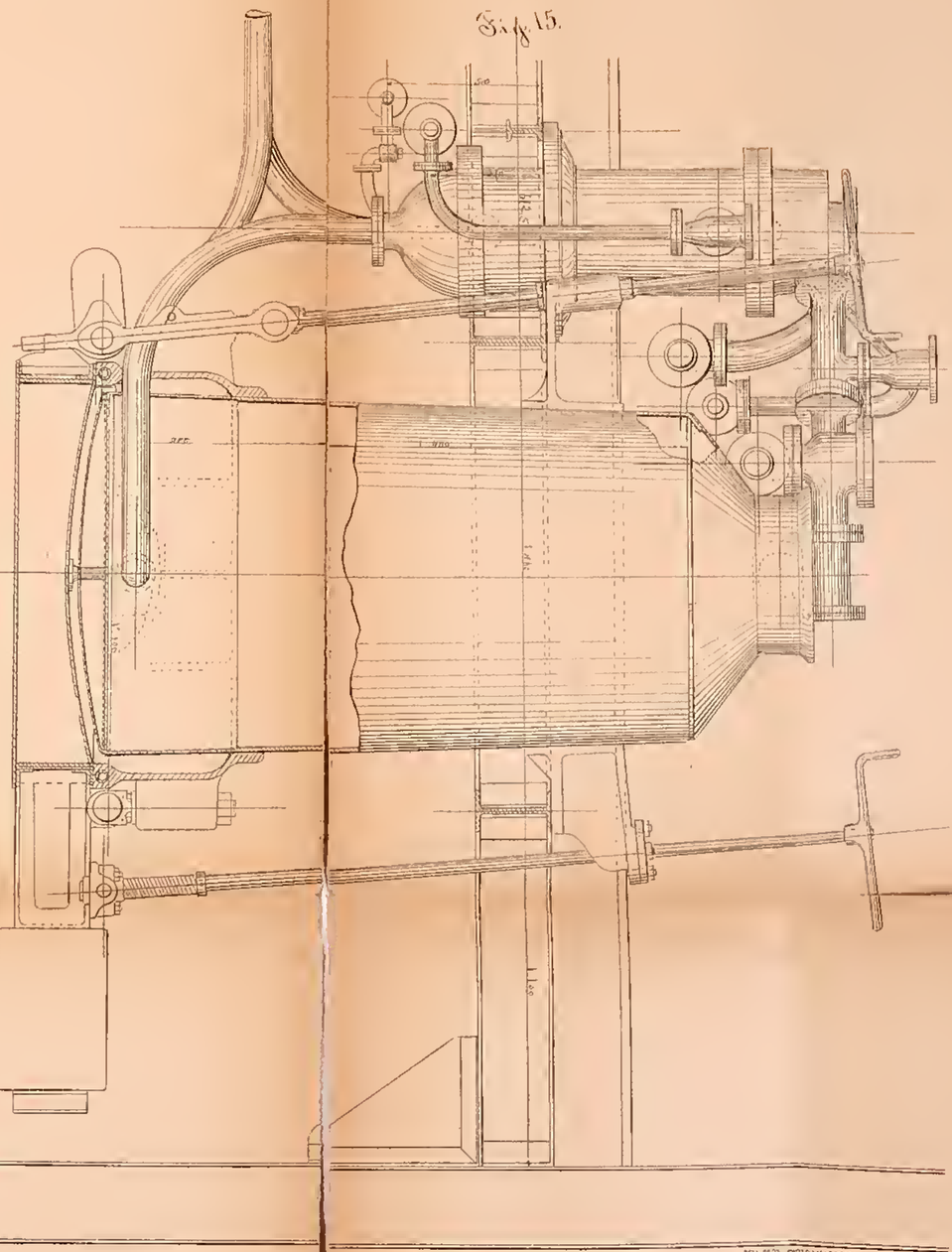
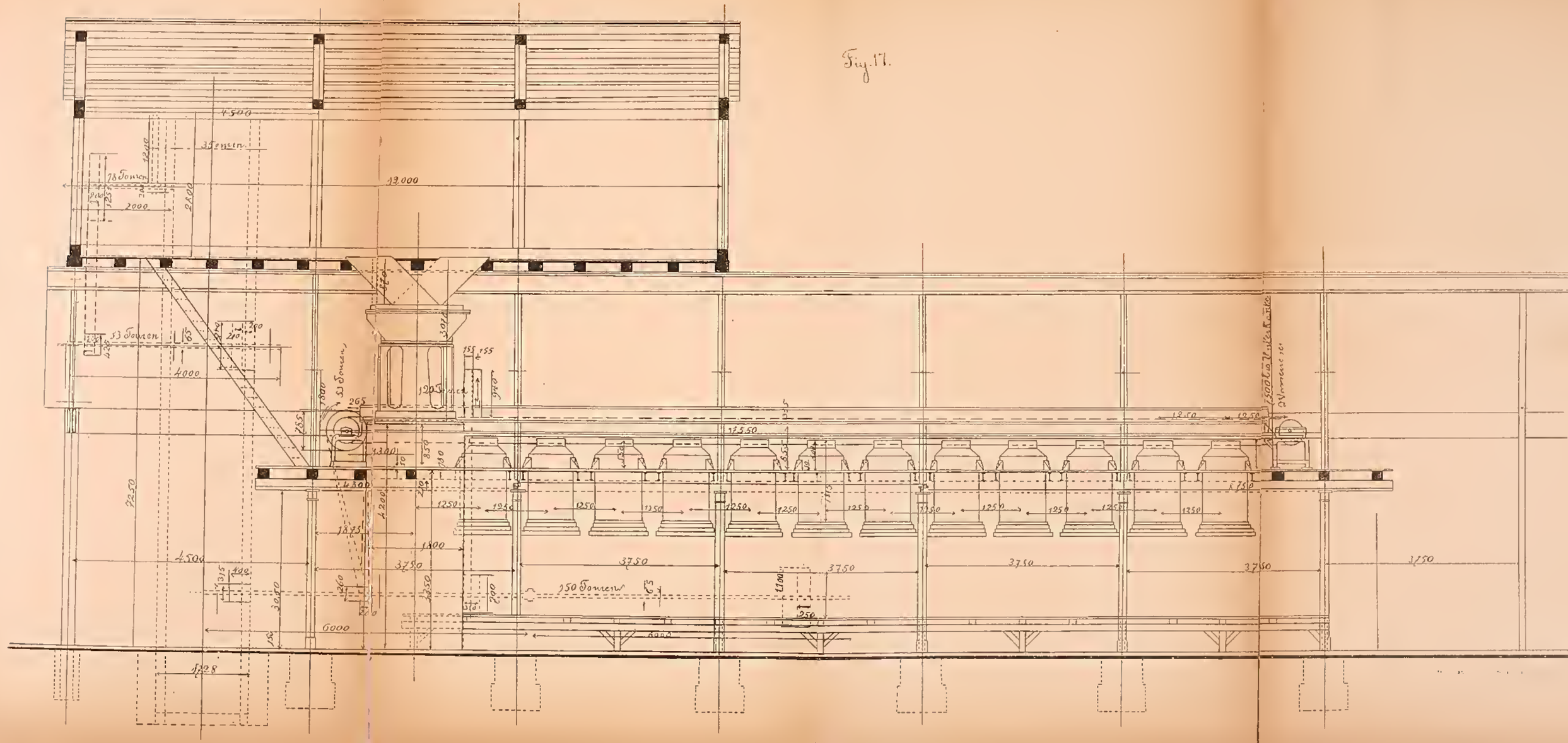


Fig. 17.

Fig. 17.


4500
35 Tonnen
13.000
18 Tonnen
2000
2400
33 Tonnen
4000
1800
265
1205
155
155
1300
12550
1250
1250
1250

mg

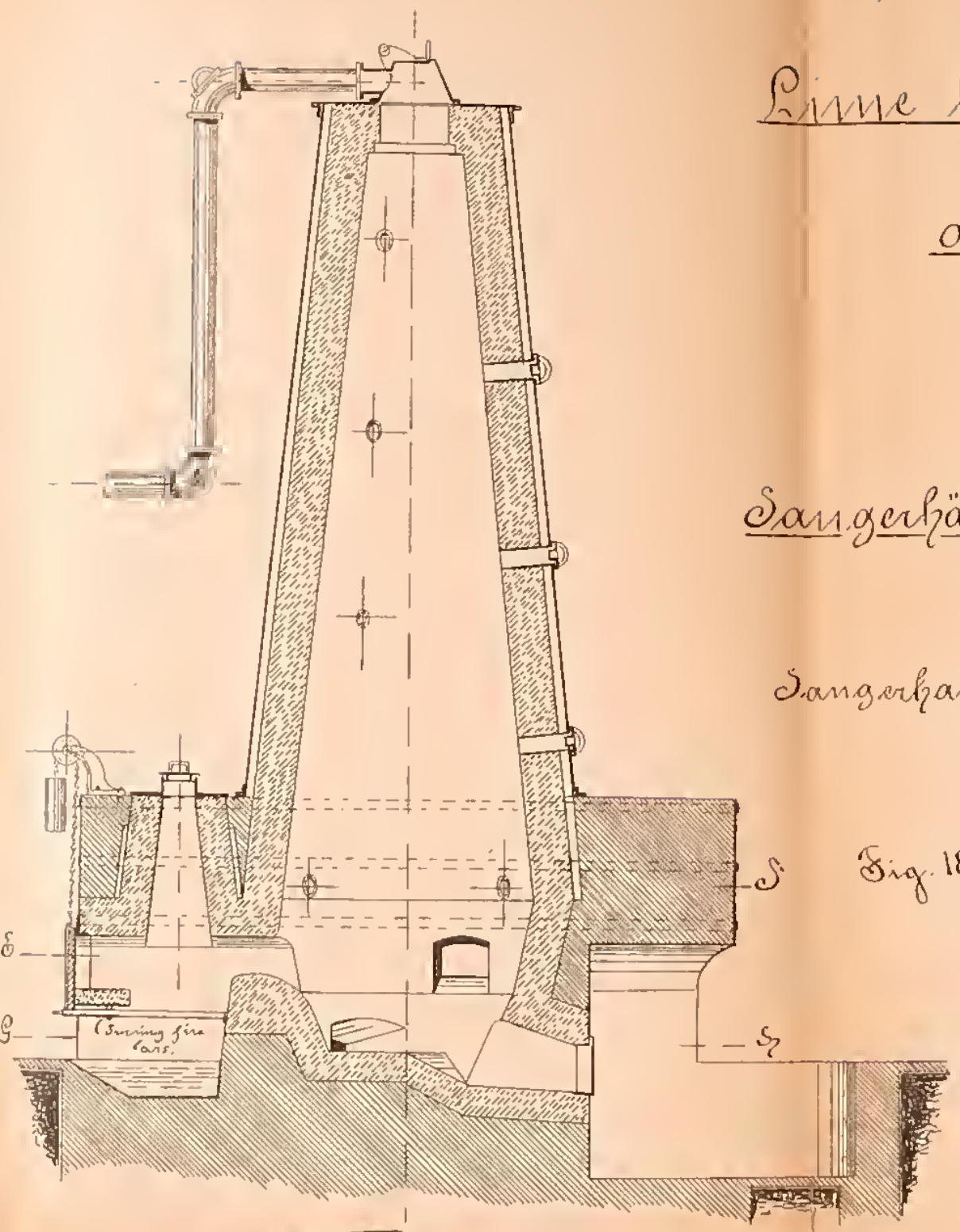
Lime kiln for the generating of carbonic acid

system of the

Sangerhäuser Actien-Maschinenfabrik

& Eisengiesserei.

Sangerhausen Germany.



Kalkofen & Saturationseinrichtung

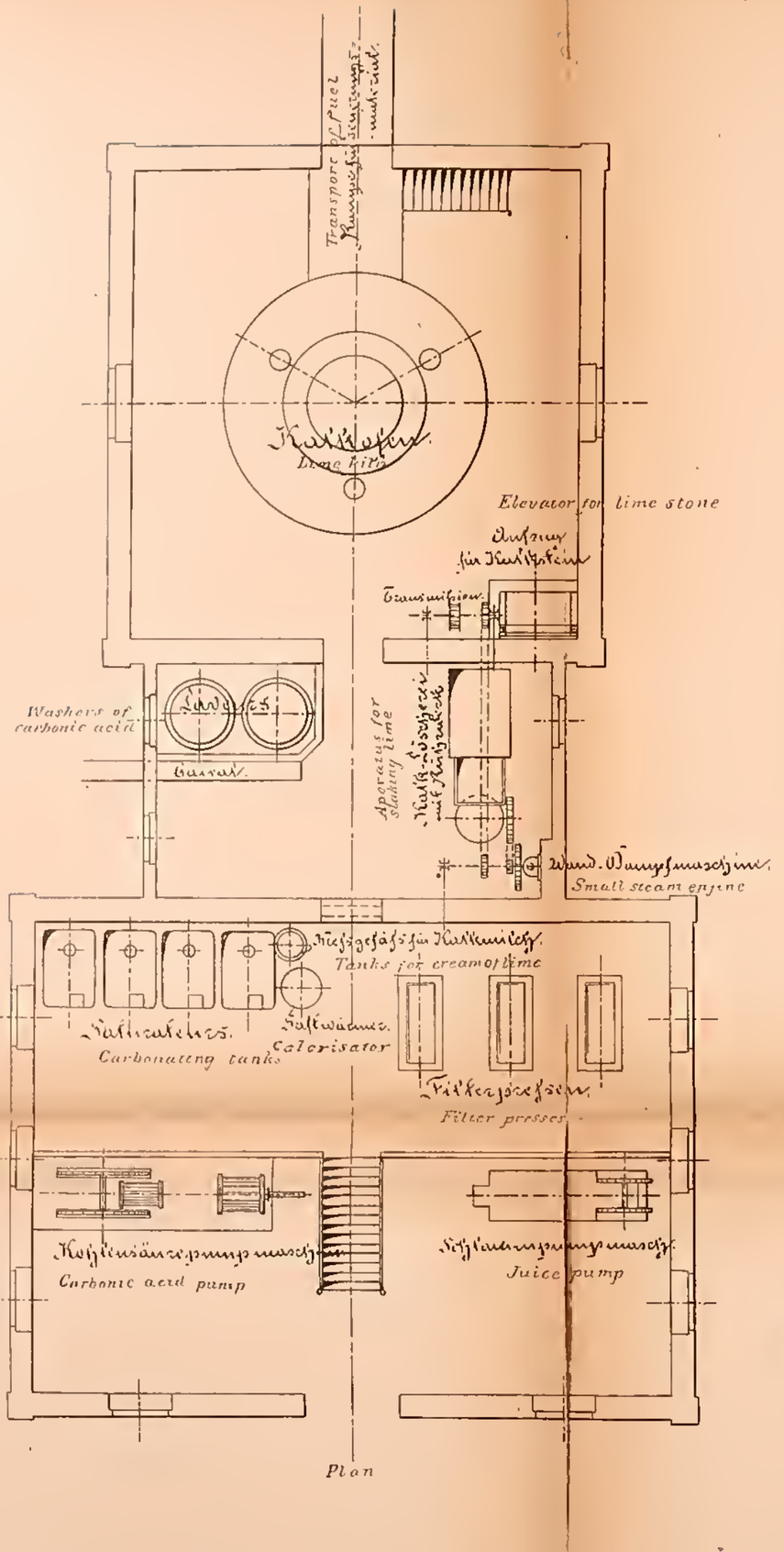
für eine Leistung von 200000 liter Saft in 24 Stunden.

Magdeburg. Sudenburg, d. 7/1 1885.

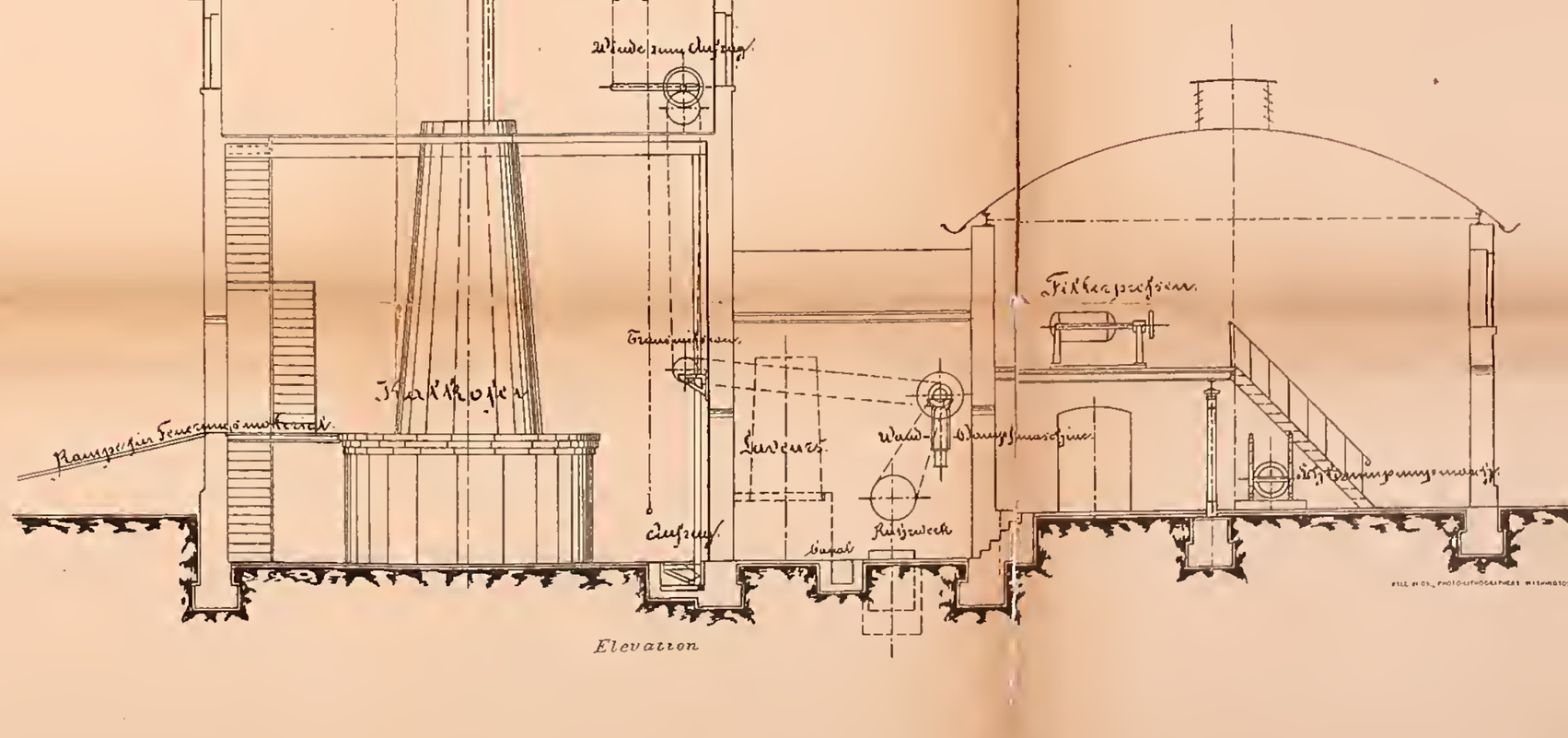
Fig 19.

Maasstab 1:

0 1 2 3 4 5 6 7 8 9 10 20 Meter.



Plan



Elevation

nt of Agricult

Schnitt C.D.

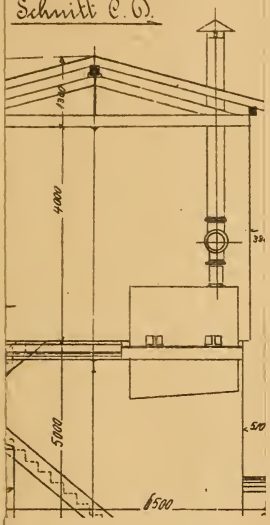
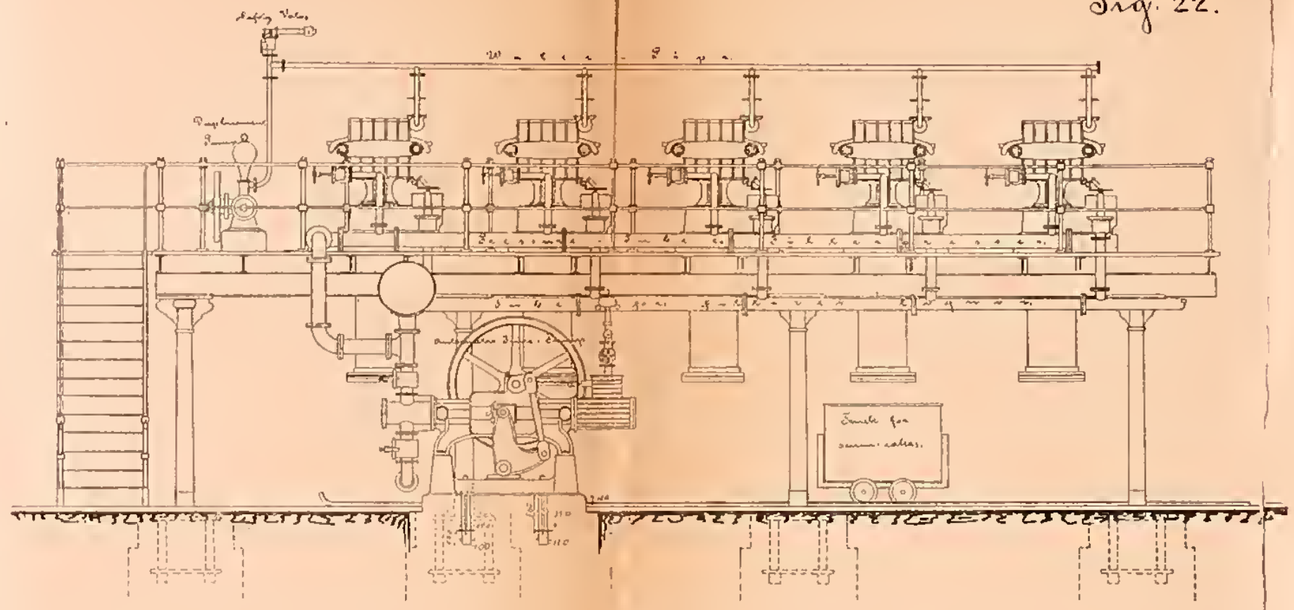
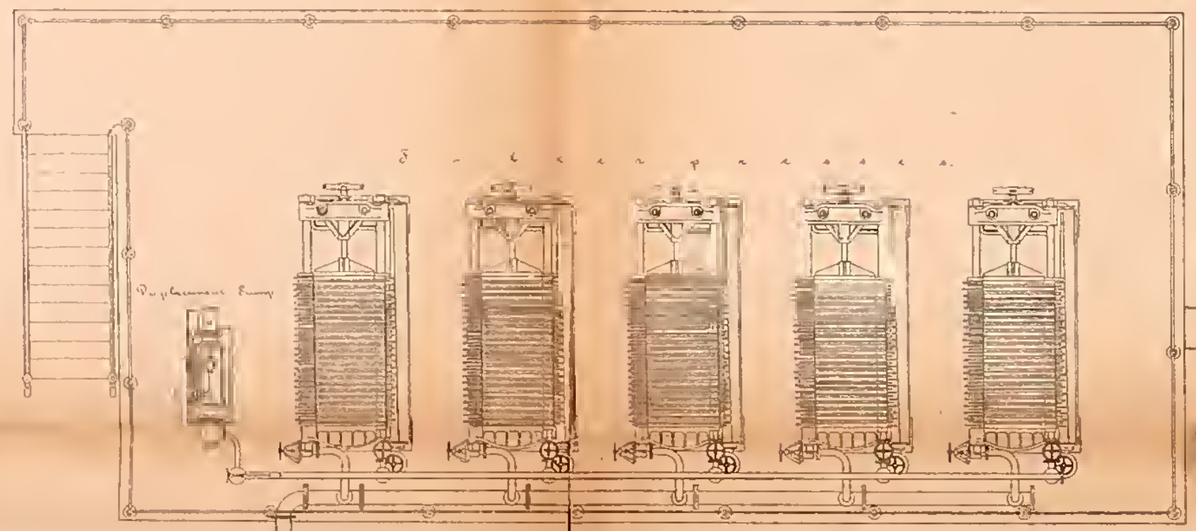
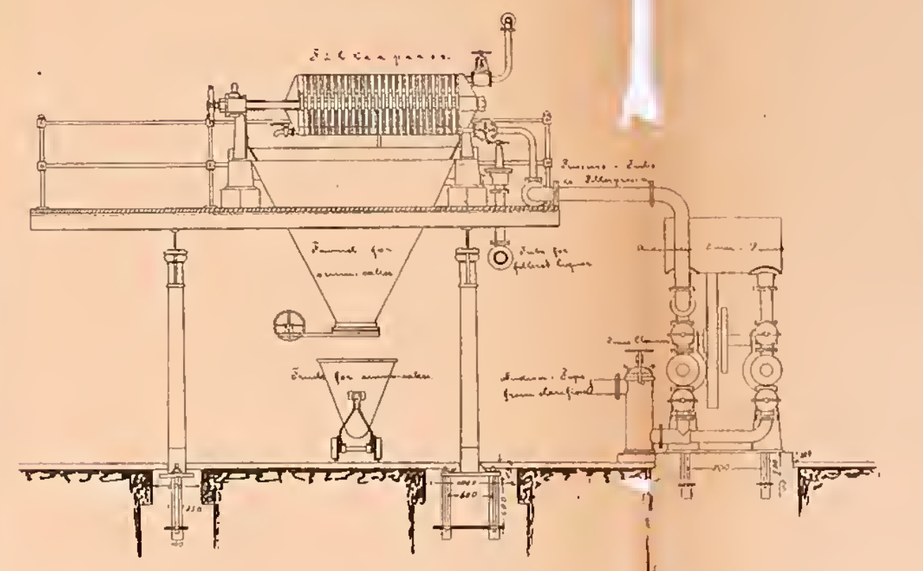


Fig. 22.







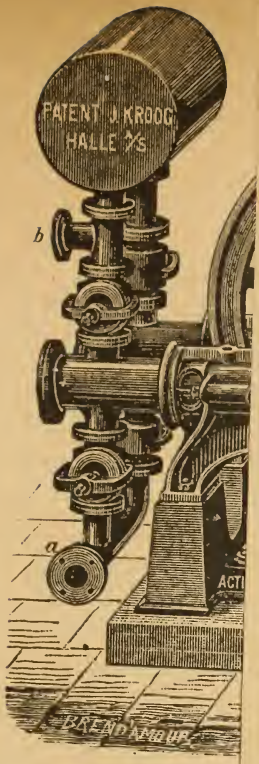
Plant of Kroog's Patent-Filterpresses

for the expression of lime-scum from the defecation of

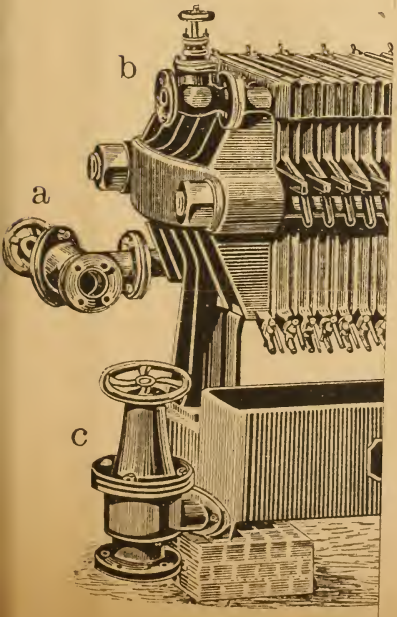
Sugar-Cane Juice

Sangerhäuser Aktien-Maschinenfabrik u. Eisengiesserei

in Sangerhausen, Germany.

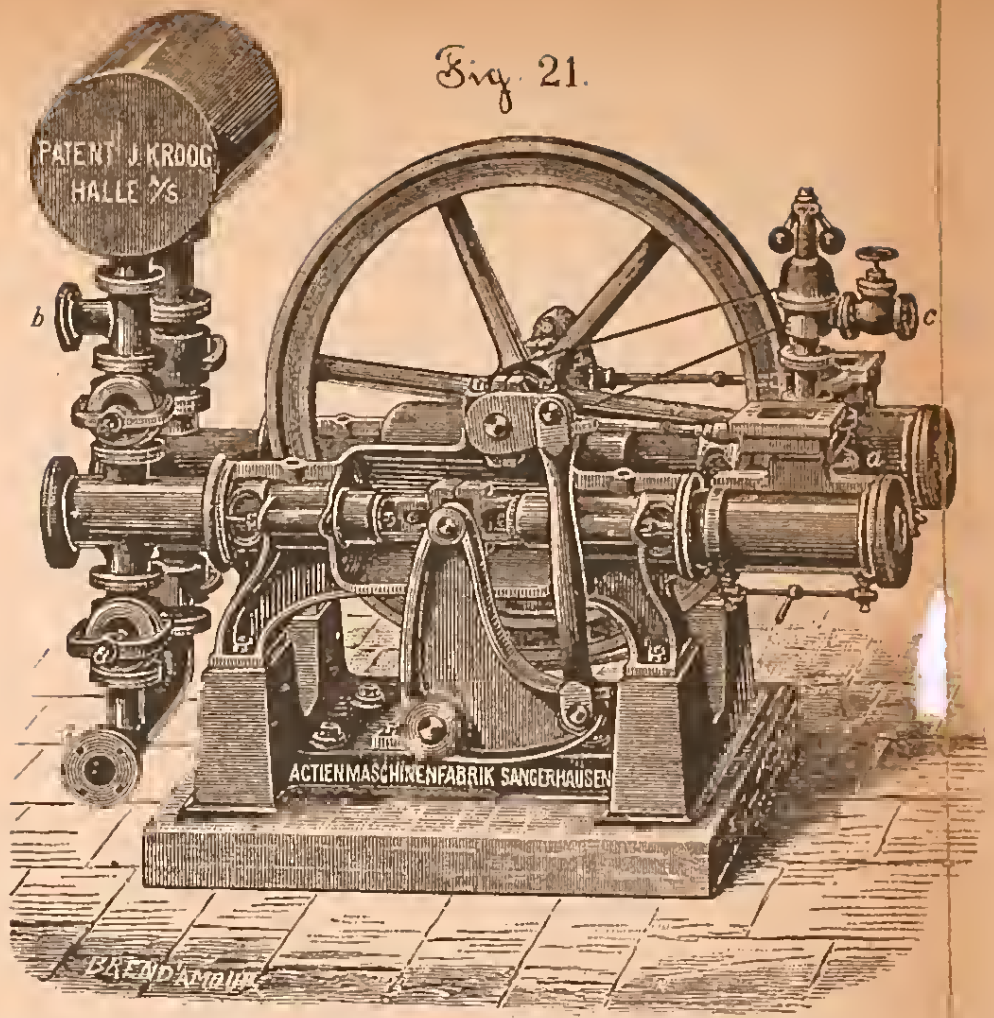


Kroog's patentir



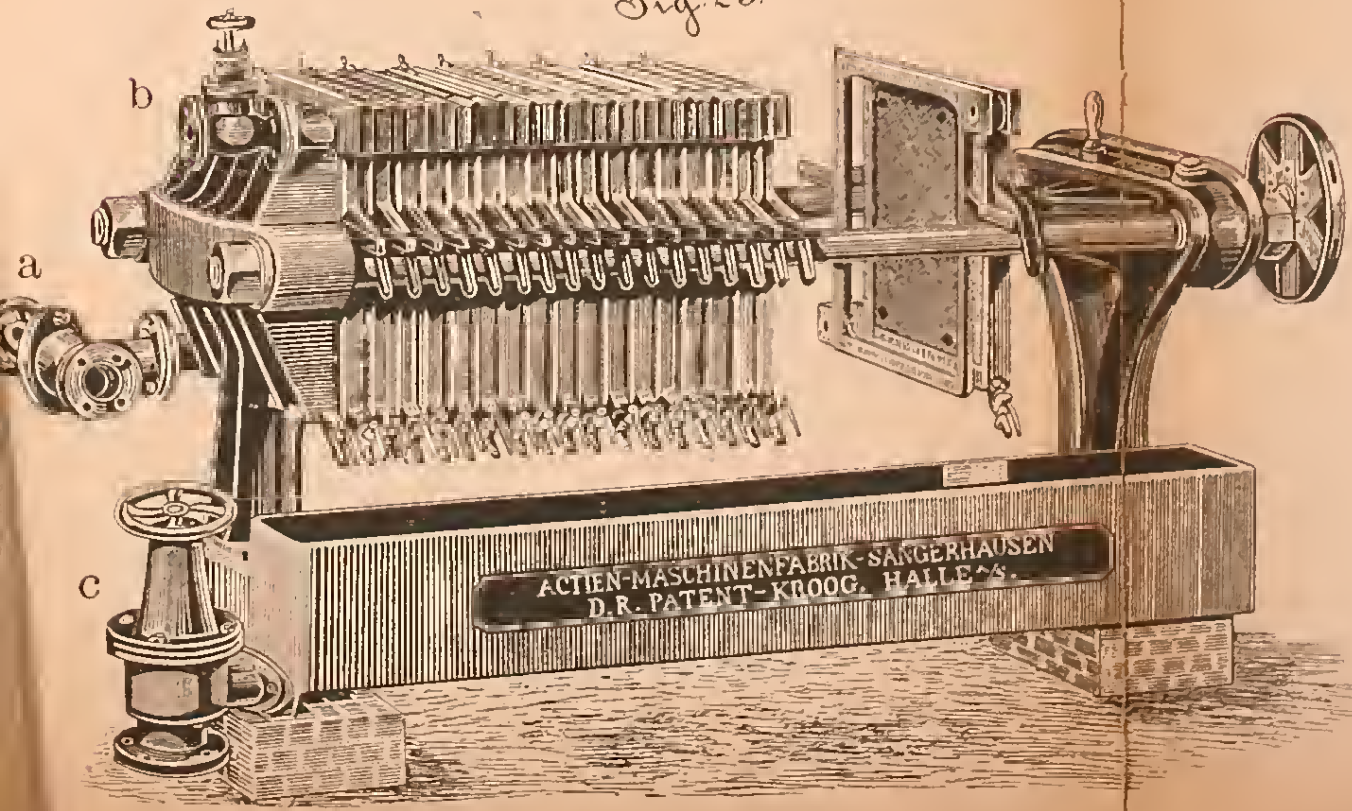
a. Juice Valve

Fig. 21.



Kroog's patentirte automatische Schlammpumpe.

Fig. 23.

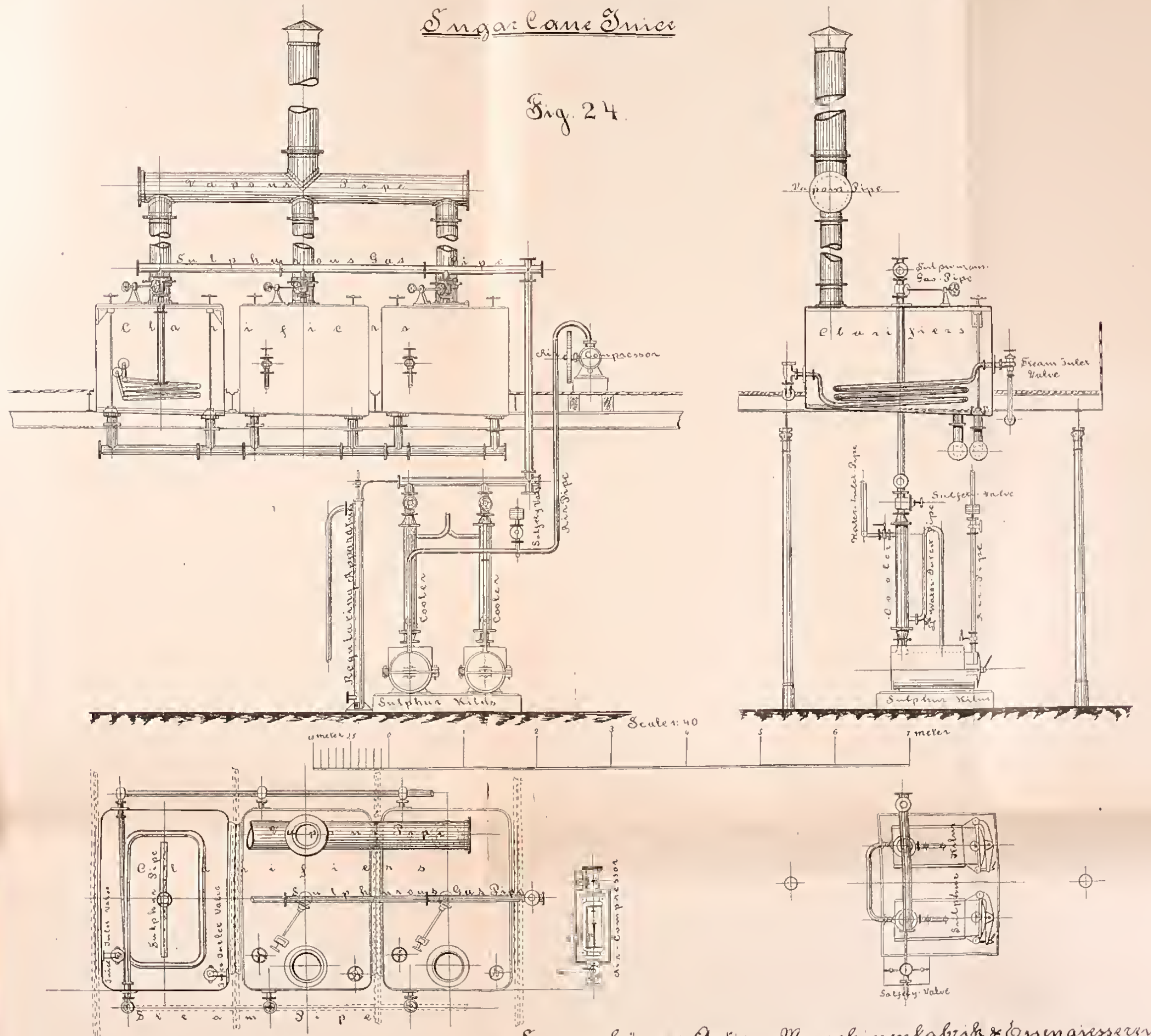


a. Juice Valve. b. Water Valve. c. Discharge Valve.

ation of

Arrangement of three Pans for Clarification and Sulphurization of Sugar Cane Juice

Fig. 24.



Sangerhäuser Actien Maschinenfabrik & Eisengiesserei.

Sangerhausen. Germany.

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